

RAQMS TES/OMI/MLS/OSIRIS data denial studies: Impacts of Satellite measurements on Tropospheric ozone

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Satellite Data provided by:

Kevin Bowman, Nathaniel Livesey (NASA/JPL)

Pawan Bartia (NASA/GSFC)

Doug Degenstein (University of Saskatchewan)

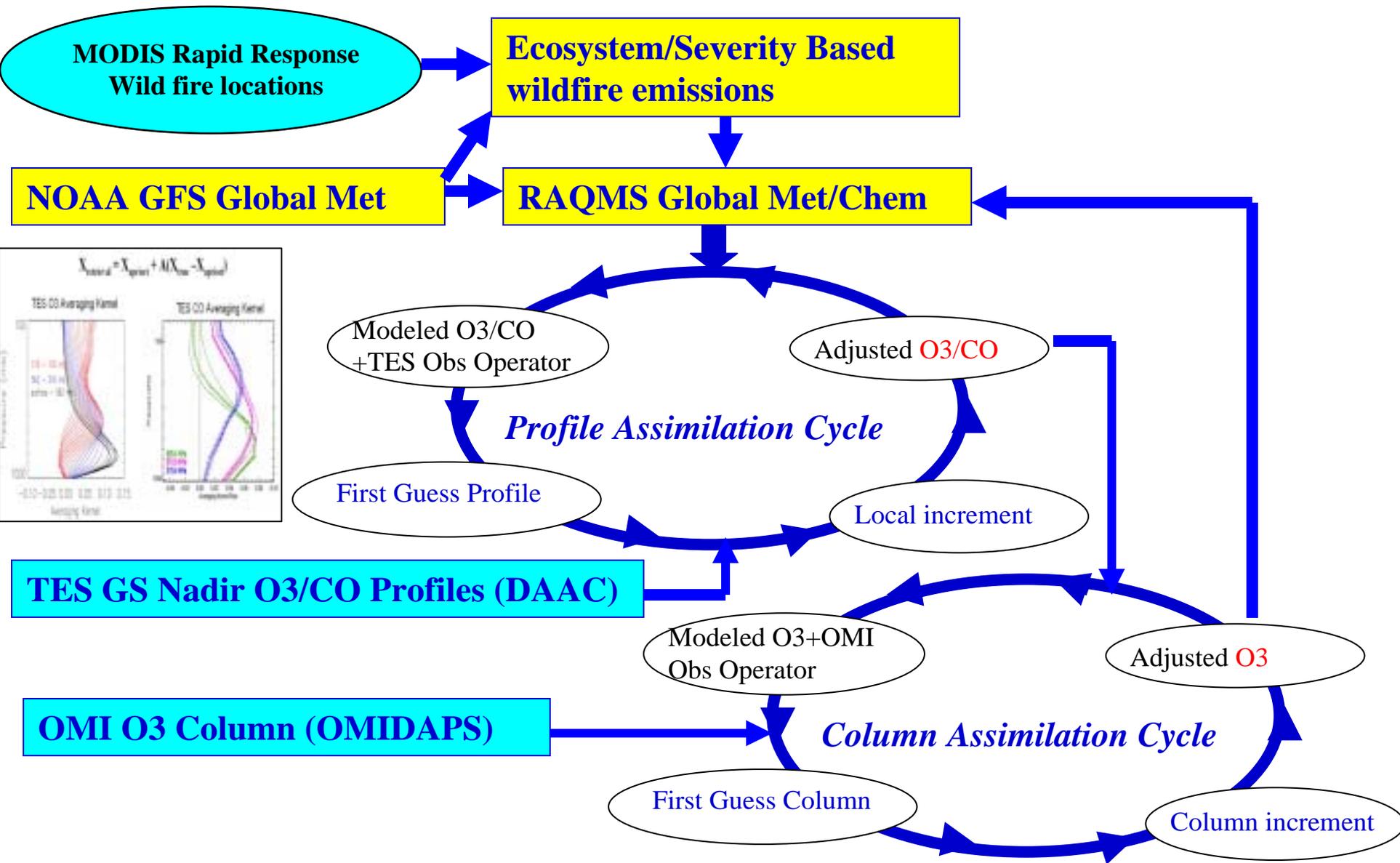
Ozonesonde Data provided by:

Anne Thompson (PSU)

NAM-CMAQ results provided by Youhau Tang

5th Annual JCSDA Workshop, Baltimore MD, June 10-11th, 2008

RAQMS_{global} (2x2) 2006 OMI/TES Reanalysis O3/CO Assimilation Procedure

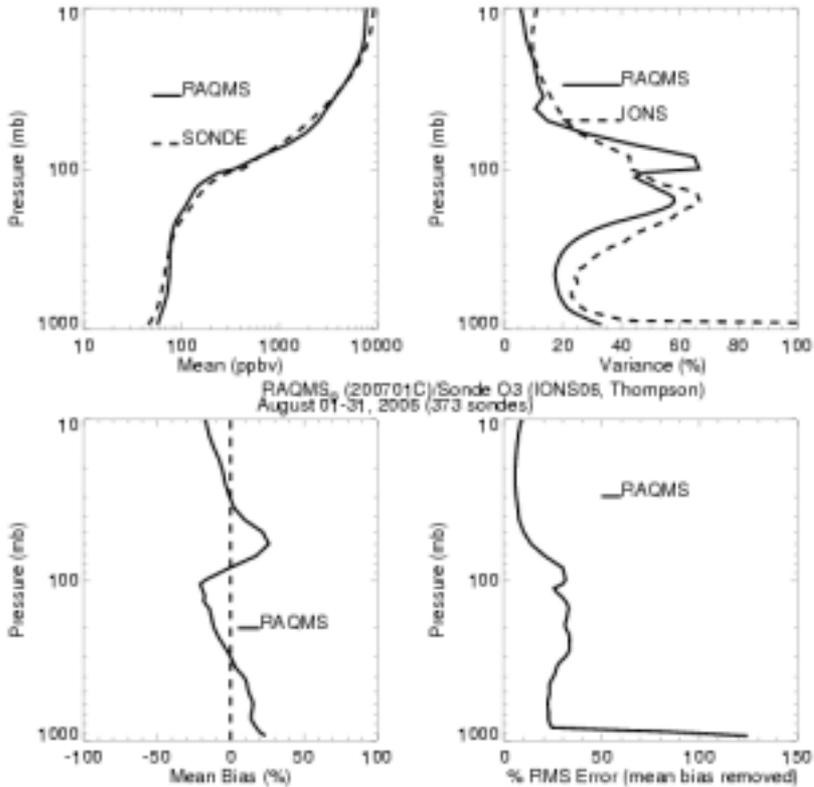


Comparison of RAQMS OMI+TES reanalysis with IONS ozonesondes (373 sondes, August, 2006)

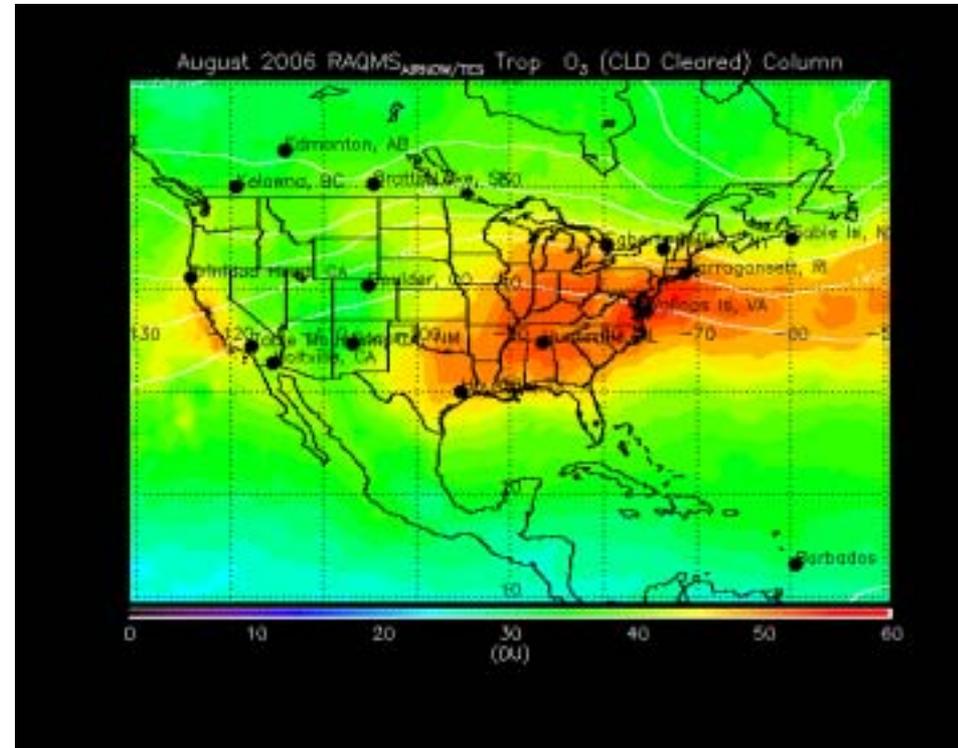


PI: ANNE M. THOMPSON
Penn State

RAQMS OMI+TES Tropospheric Ozone Column (August 01-31, 2006)



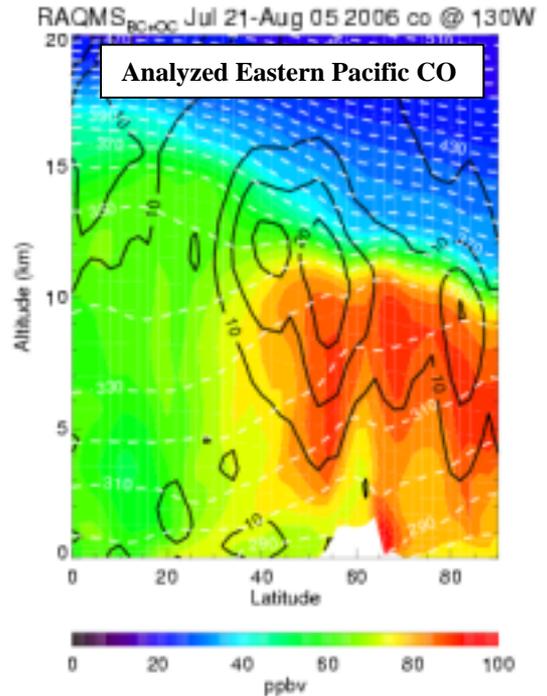
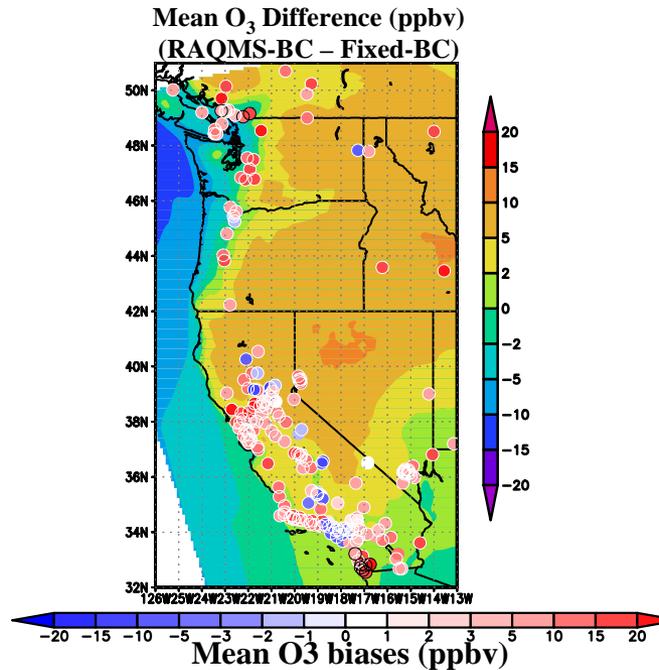
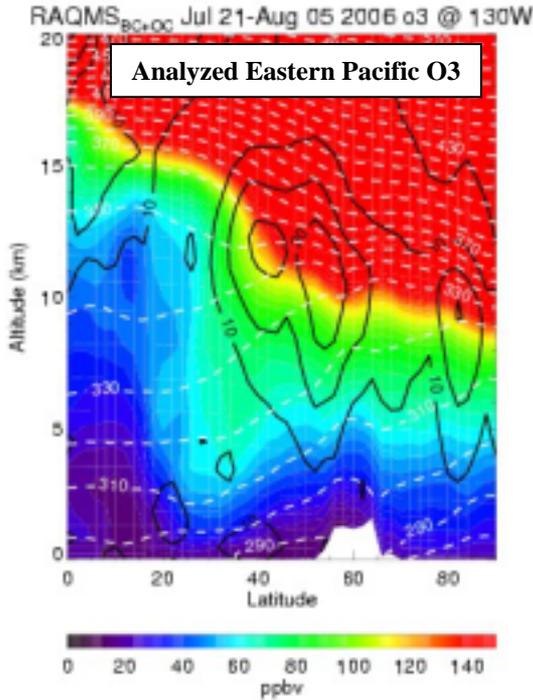
Tropospheric biases: +/- 20%



Impact of Global BC on regional AQ Prediction¹

Assessment using pre-operational NOAA/NWS NAM-CMAQ 12km forecast

(July 21-August 5, 2006)



•RAQMS lateral Boundary Conditions (BC) show enhanced O₃ and CO between the Sub-tropical and Polar Jets

•RAQMS lateral Boundary Conditions lead to 10-15 ppbv reductions in off-shore surface ozone and 5-10 ppbv increases in surface ozone over mountain regions of the western US.

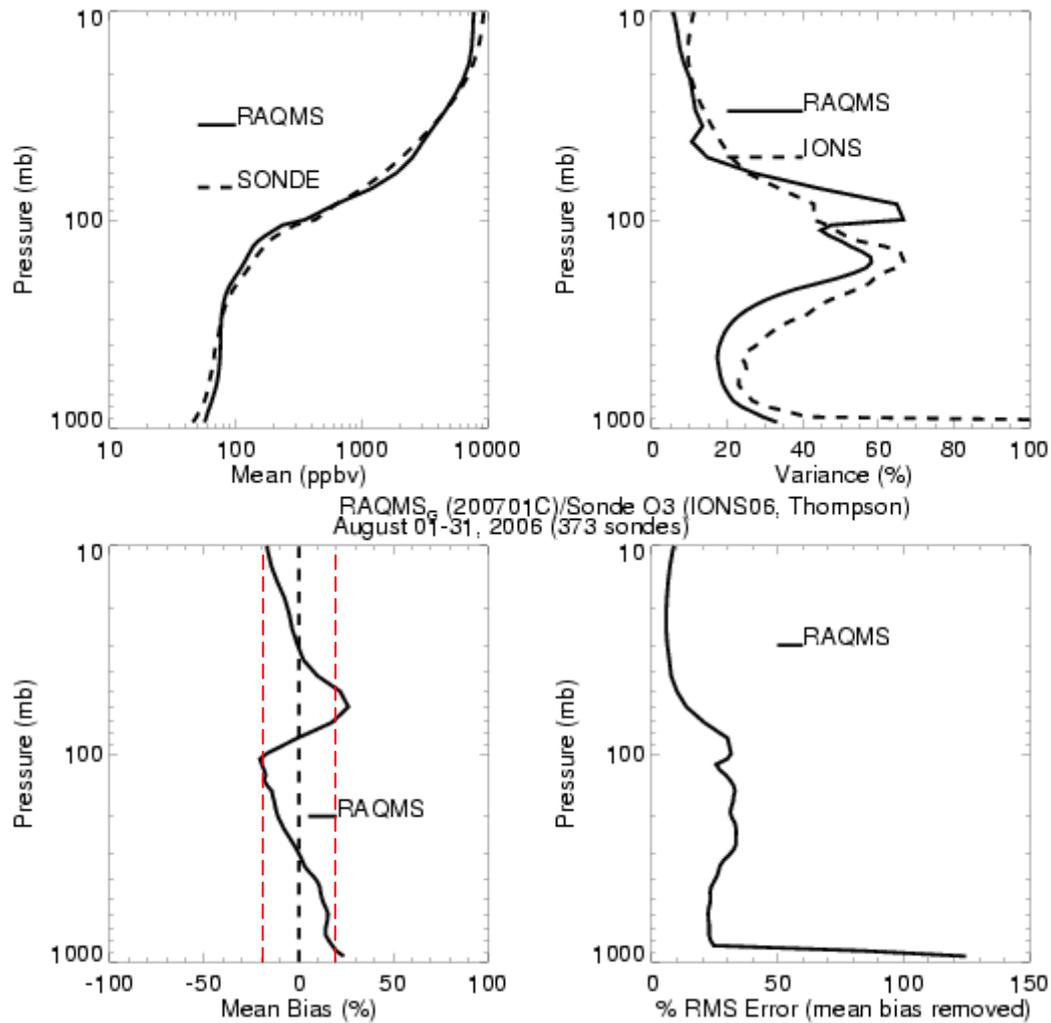
•Comparison with EPA AIRNow surface ozone west of -115°W shows improved slope and correlations but increased positive bias.

NAM-CMAQ vs AIRNOW

	West of -115°W
Static BC	S=0.804 R=0.691 MB=4.7 ppbv
RAQMS BC	S=0.914 R=0.703 MB=7.1 ppbv

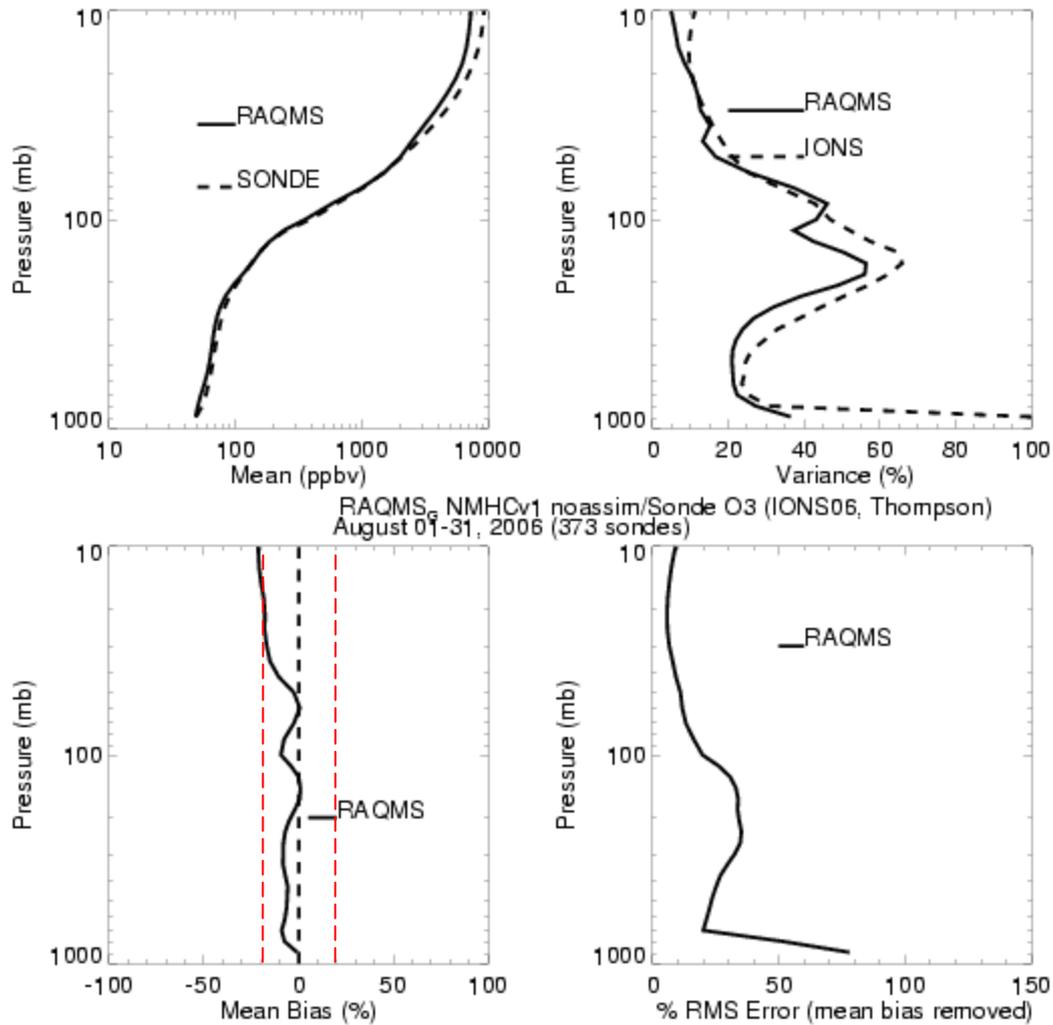
¹Tang, Y., et al., (2007) The Impact of Lateral Boundary Conditions on CMAQ Predictions over the Continental US: a Sensitivity Study Compared to Ozonsonde Data, extended abstract submitted to the 6th Annual CMAS Conference, UNC-Chapel Hill, NC

August 2006 OMI+TES ASSIM vs IONS



Tropospheric biases: +/- 20%

August 2006 NO ASSIM vs IONS (July 15, 2006 OMI+TES IC)



Tropospheric biases: -10%

RAQMS 2006 Data Denial Study

Time period: August 2006

Initial Conditions: July 15th, 2006

(Baseline RAQMS OMI+TES ozone analysis)

Validation: 2006 IONS ozonesonde network (373 sondes)

Ozone Analysis:

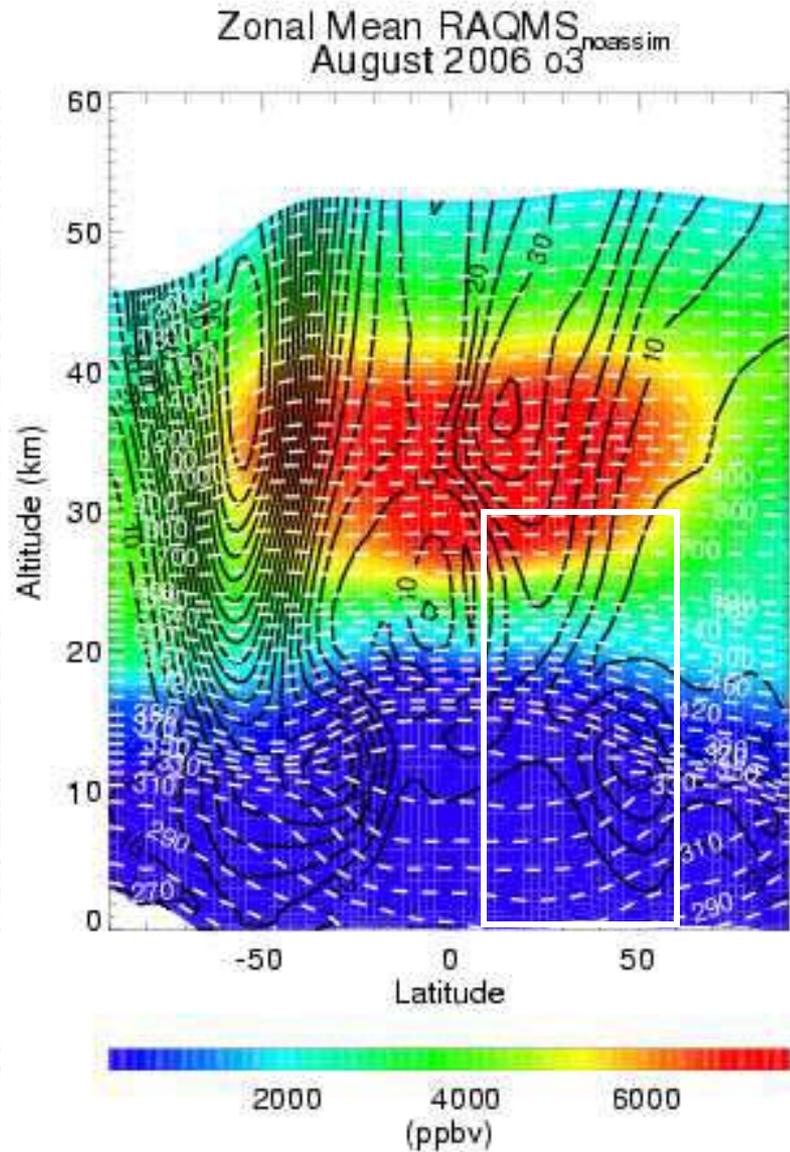
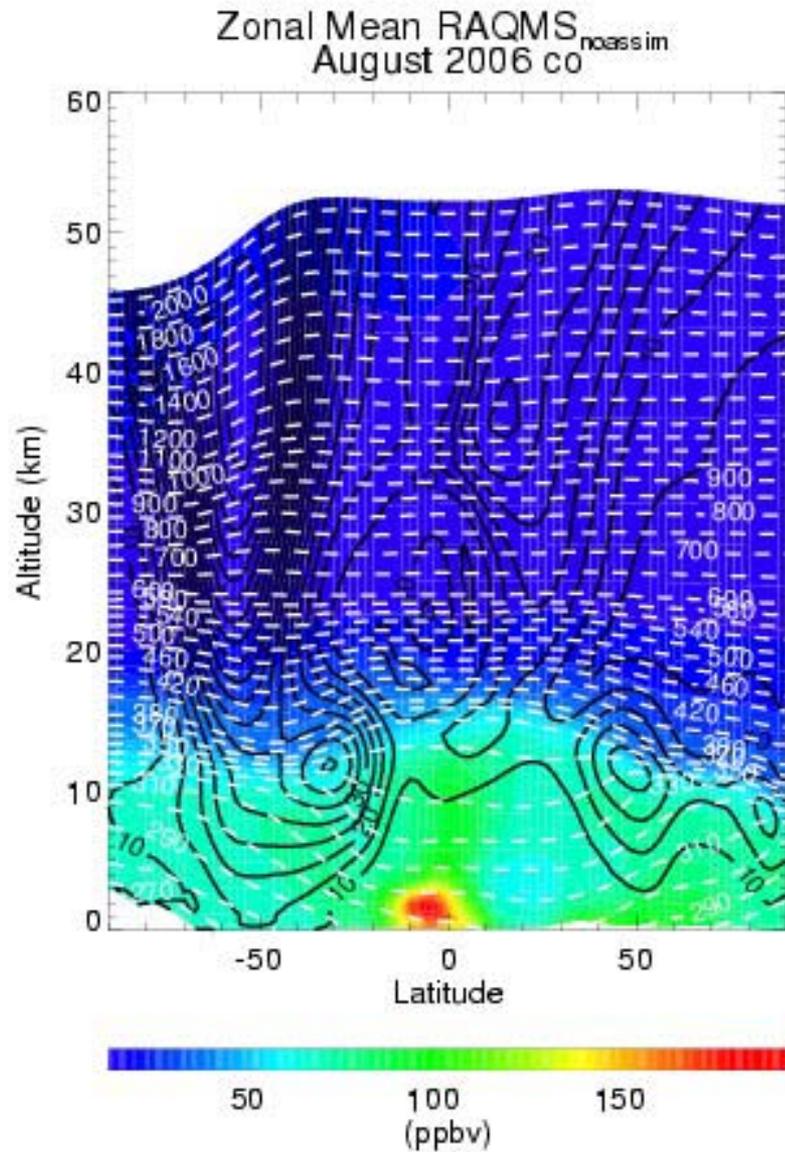
- Optimal Interpolation (IO) univariate (Pierce et al., 2007)
- OSIRIS assimilation restricted to tropopause and above
- MLS assimilation restricted to tropopause (or 246mb) and above
- unified online troposphere/stratospheric chemistry for first guess

Procedure:

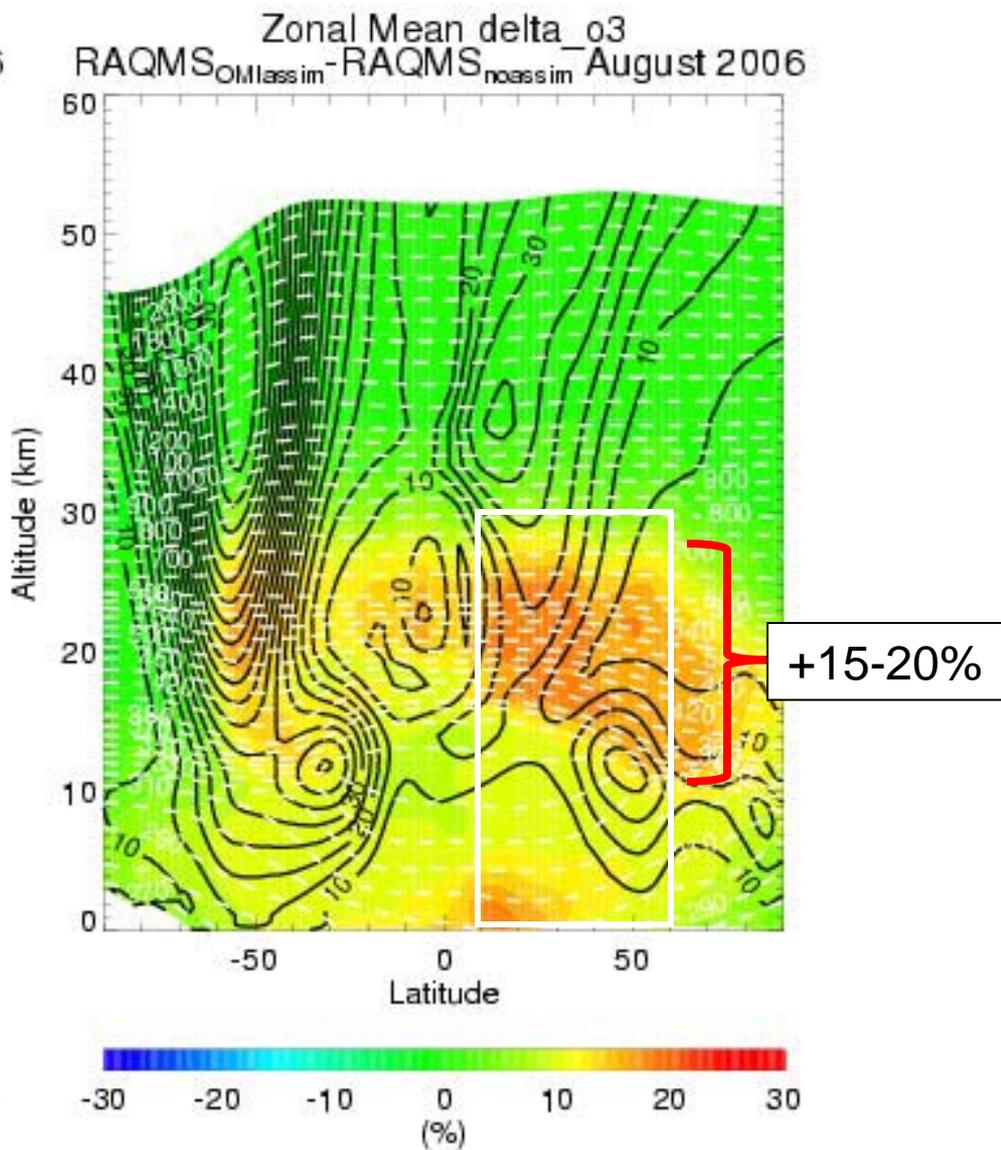
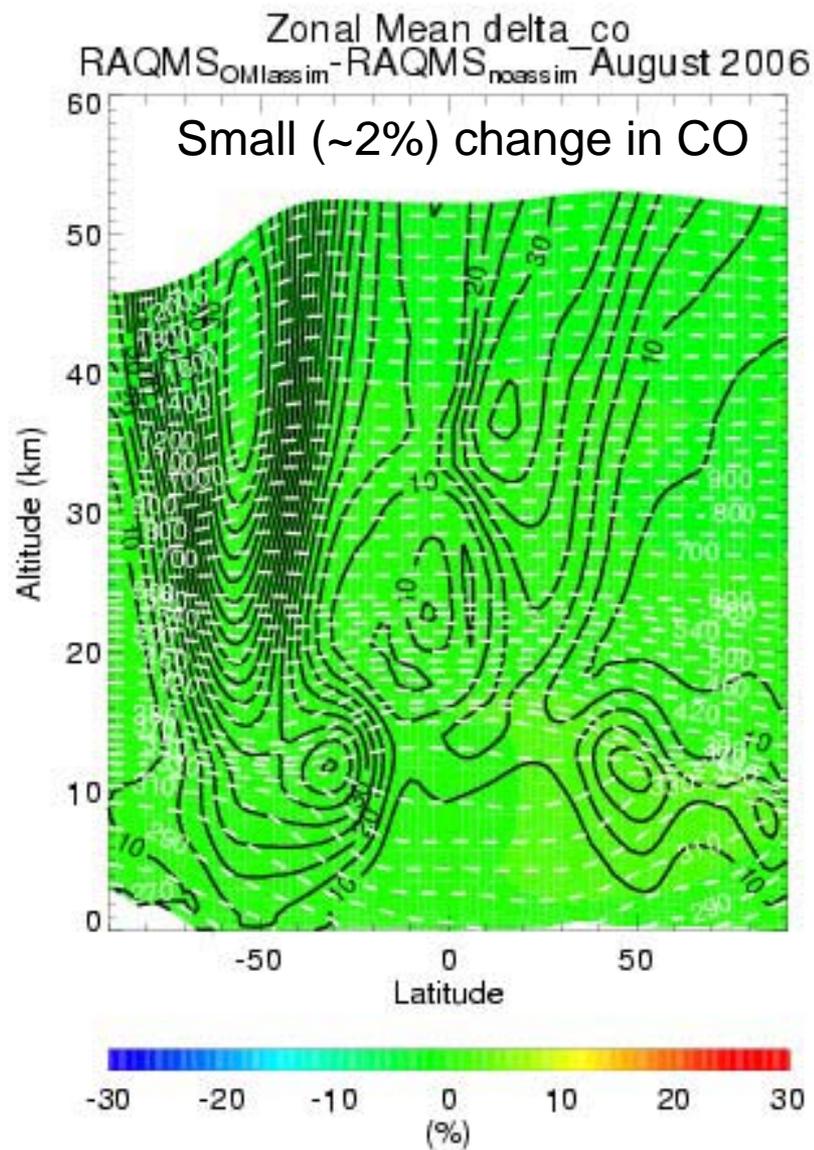
Compare RAQMS analyses with ozonesonde

- 1) No Assimilation
- 2) OMI (Cloud Cleared) only
- 3) TES (O₃&CO) only
- 4) MLS + TES CO
- 5) OSIRIS (Limb Scattering) + TES CO

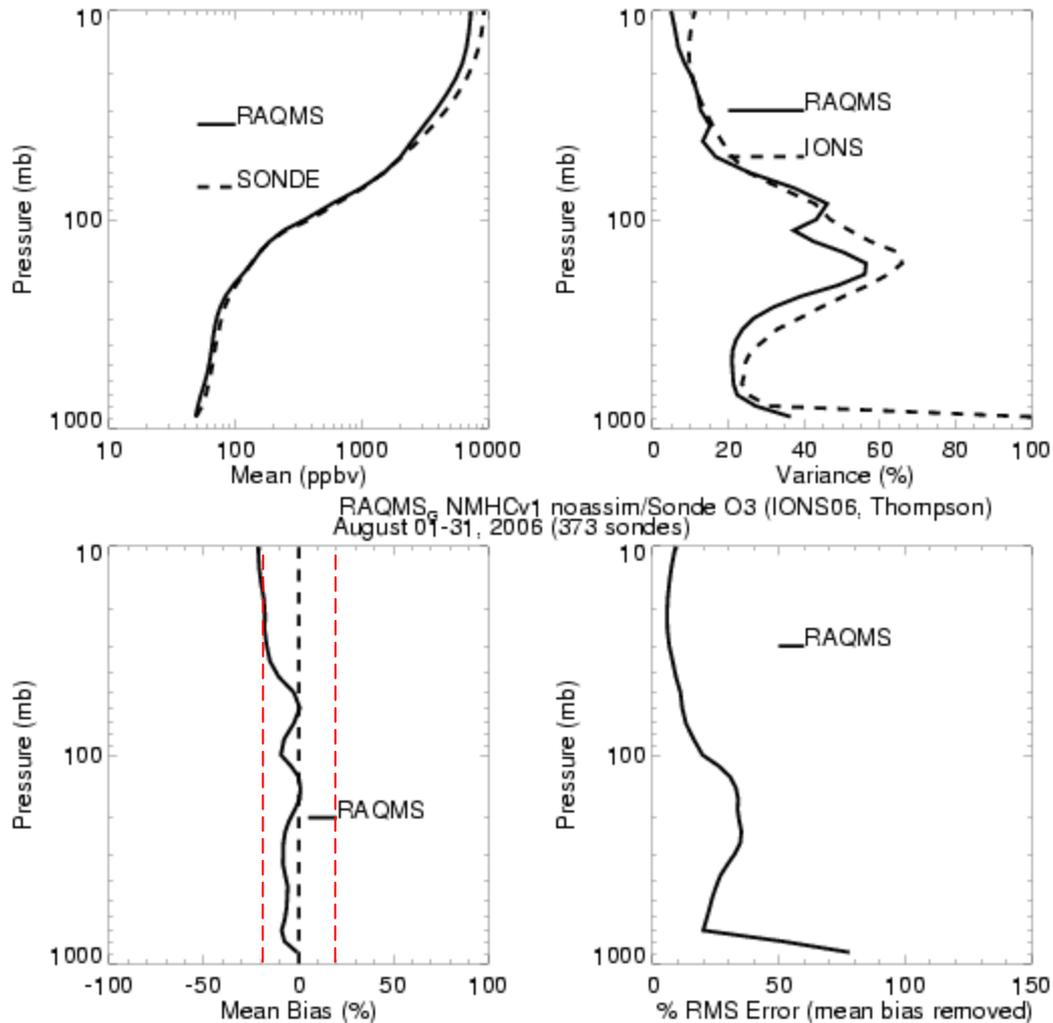
August 2006 NO ASSIM Zonal mean CO/O3 (July 15, 2006 OMI+TES IC)



August 2006 OMI Assim-NO ASSIM Zonal mean Delta CO/O3 (July 15, 2006 OMI+TES IC)

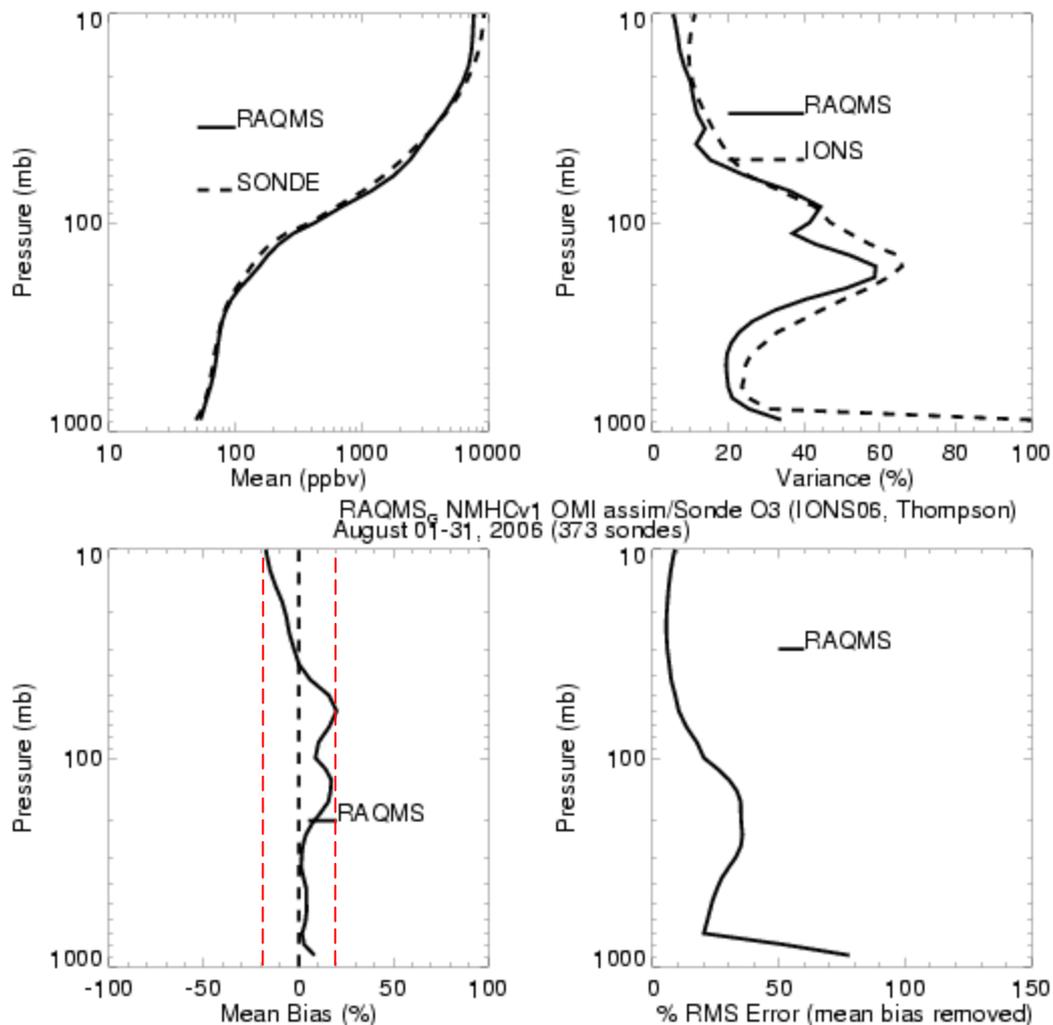


August 2006 NO ASSIM vs IONS (July 15, 2006 OMI+TES IC)



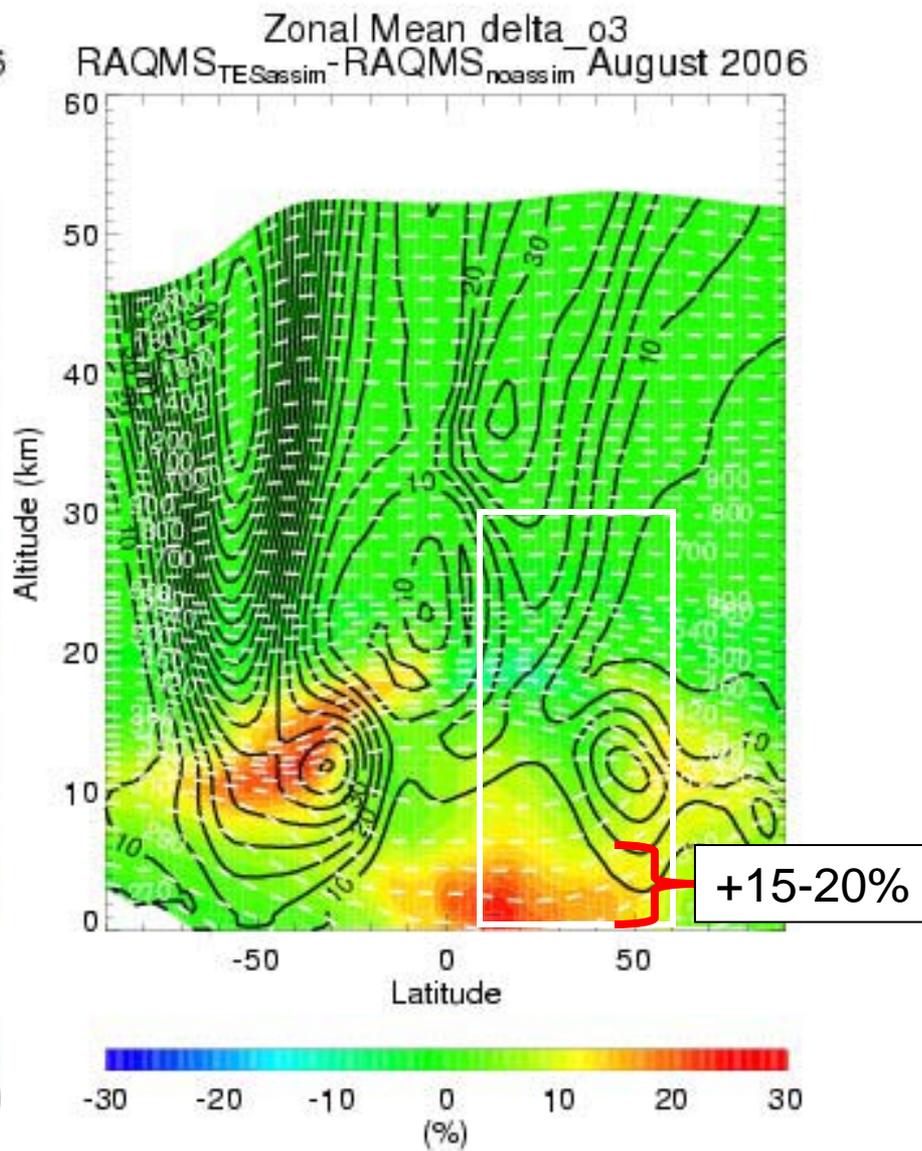
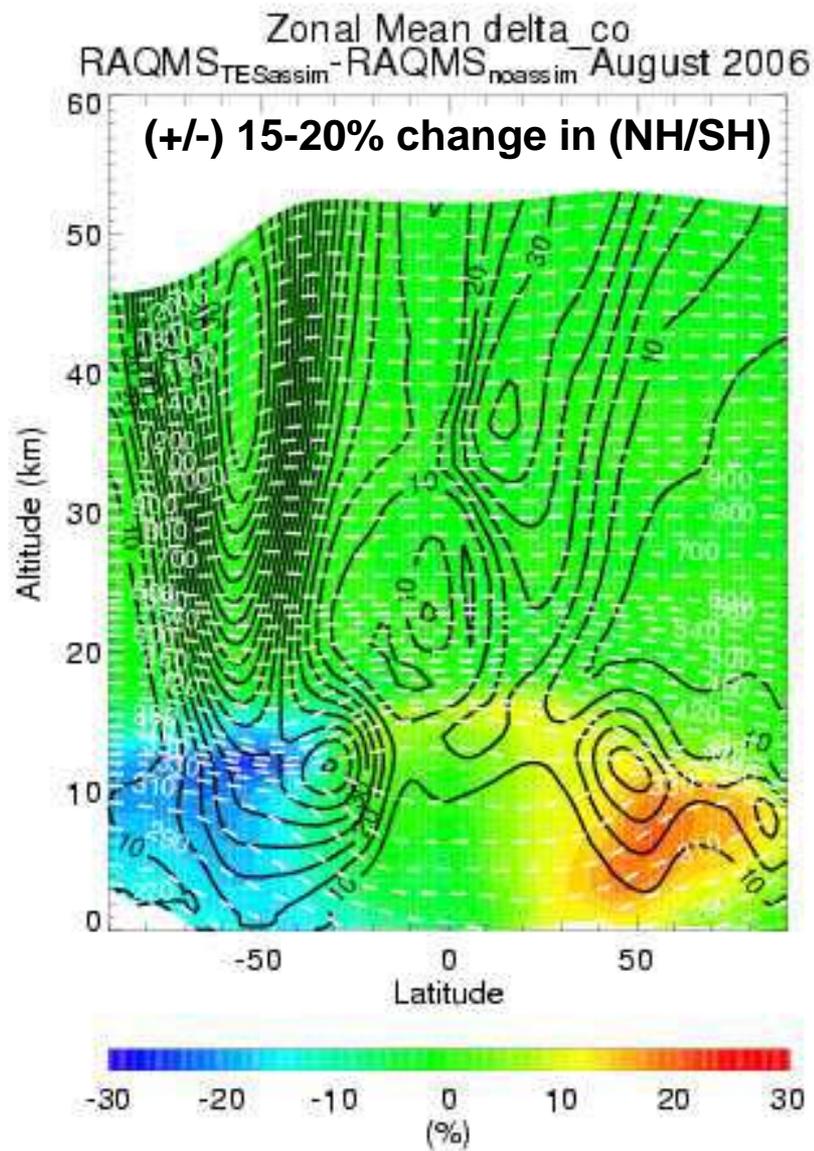
Tropospheric biases: -10%
Stratospheric biases: -20%

August 2006 OMI ASSIM vs IONS (July 15, 2006 OMI+TES IC)

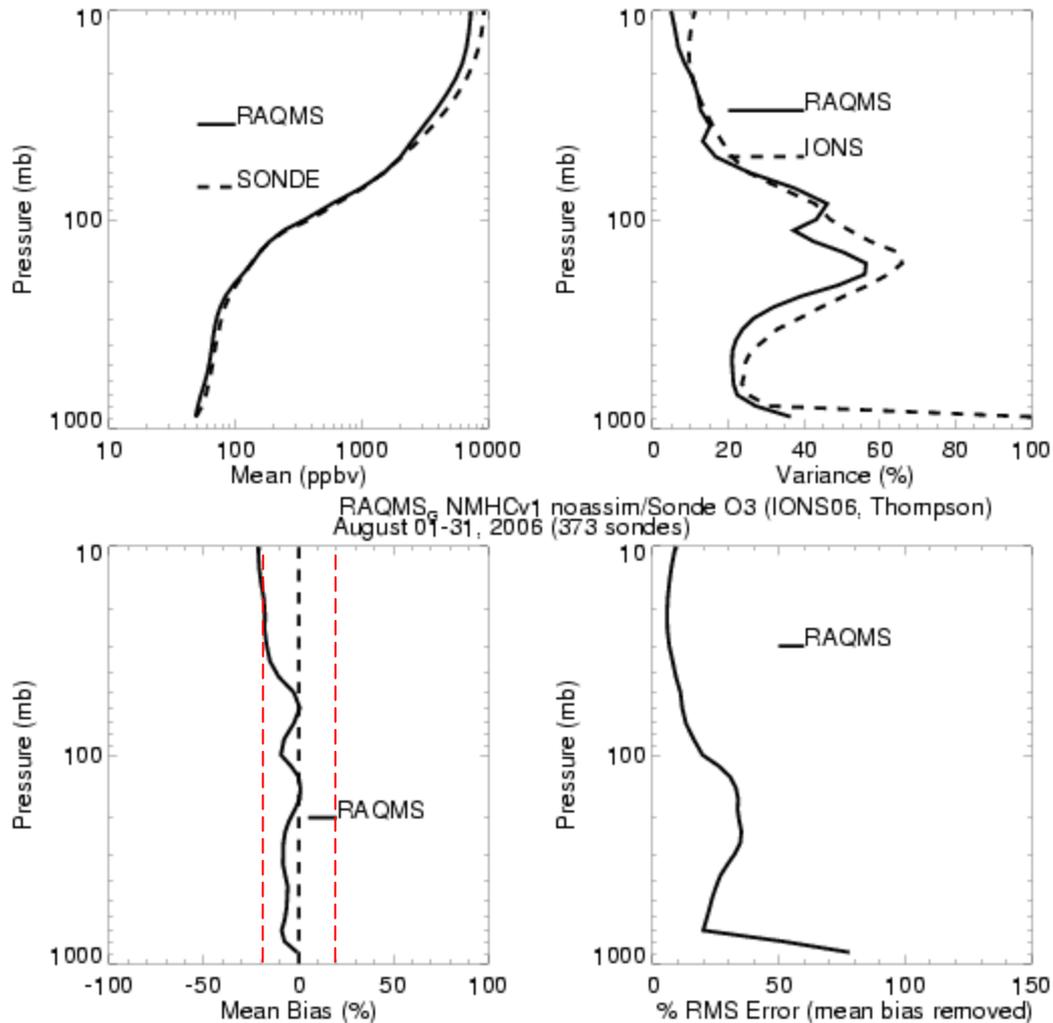


Lower Tropospheric Biases: < 10%
Upper Tropospheric/Lower Stratospheric biases: +20%

August 2006 TES Assim-NO ASSIM Zonal mean Delta CO/O3 (July 15, 2006 OMI+TES IC)

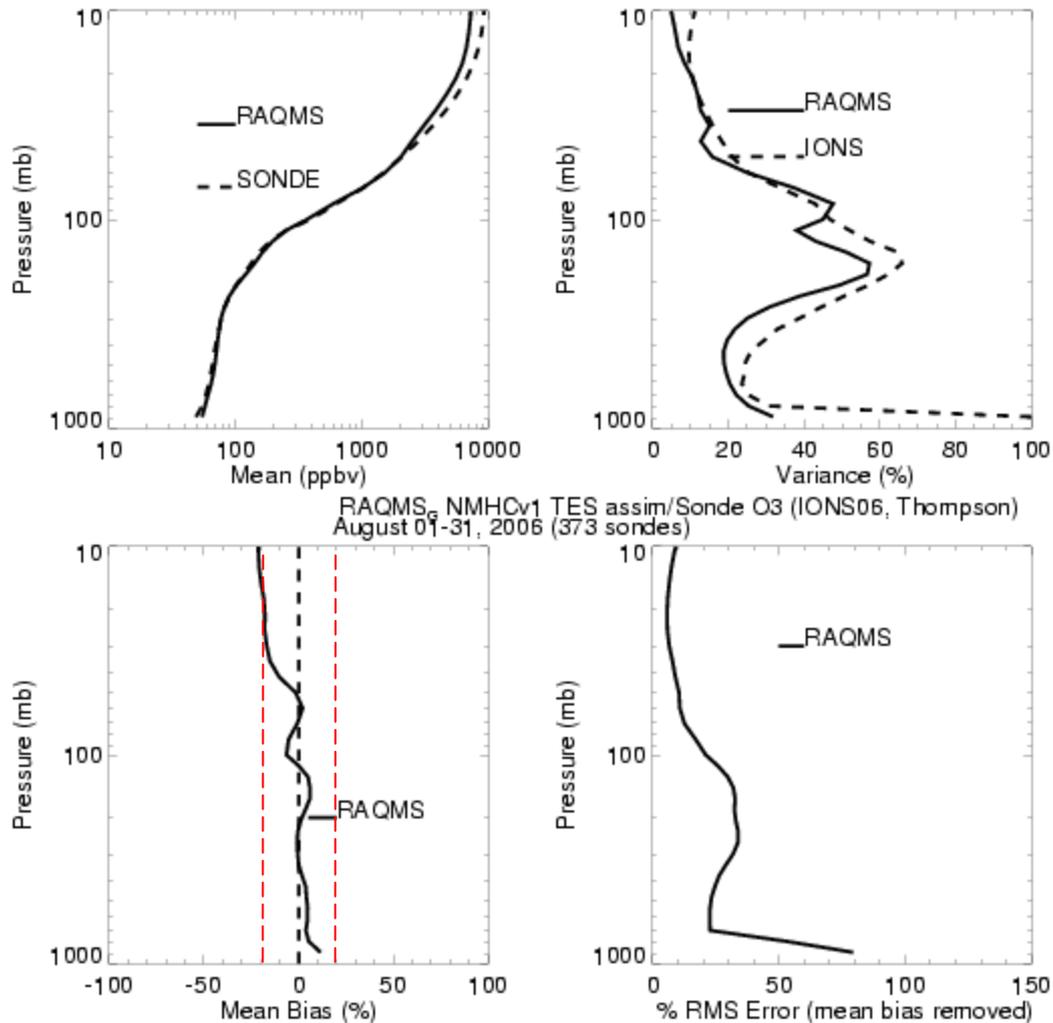


August 2006 NO ASSIM vs IONS (July 15, 2006 OMI+TES IC)



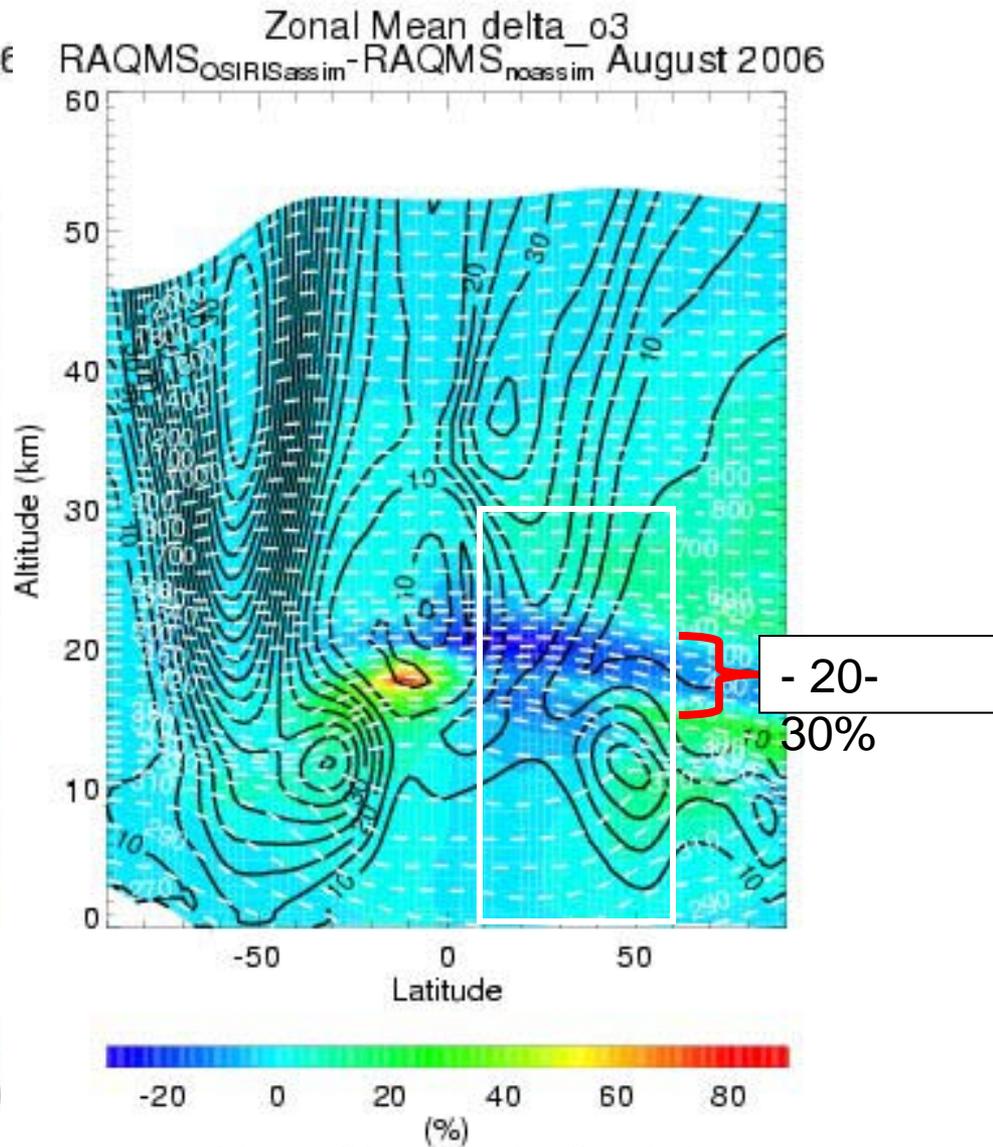
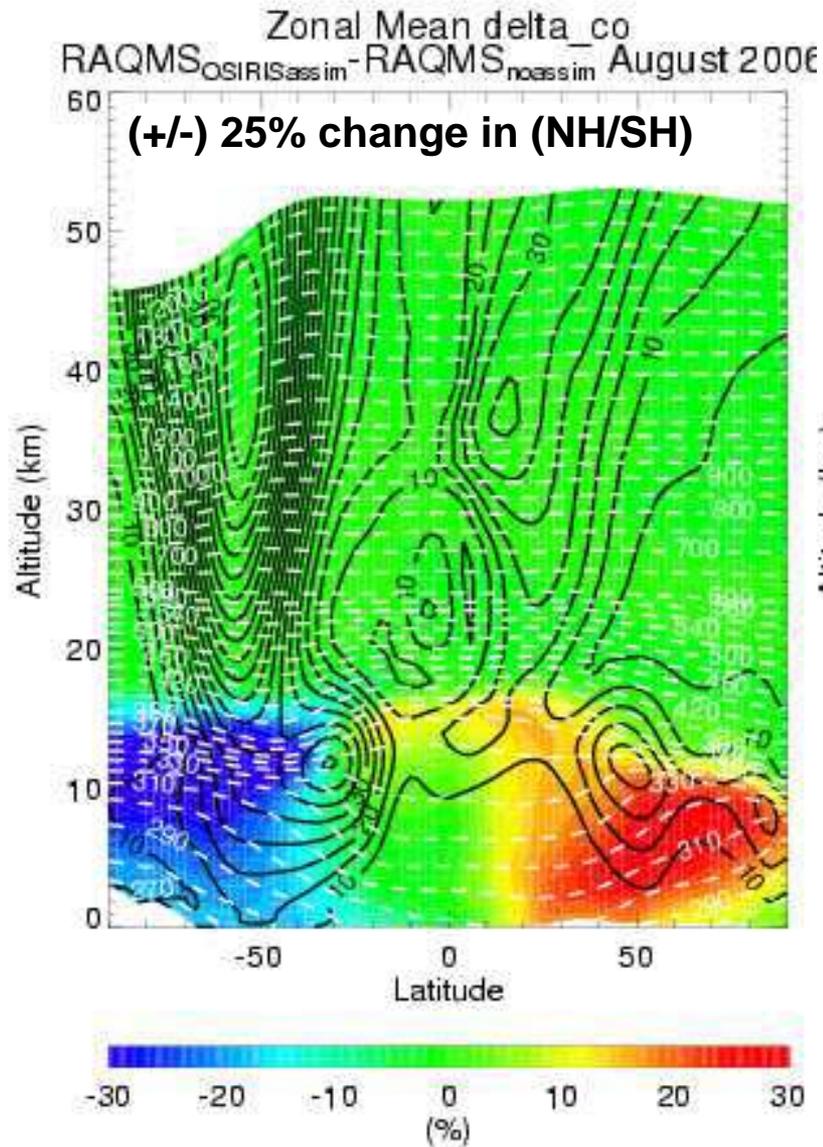
Tropospheric biases: -10%
Stratospheric biases: -20%

August 2006 TES ASSIM vs IONS (July 15, 2006 OMI+TES IC)



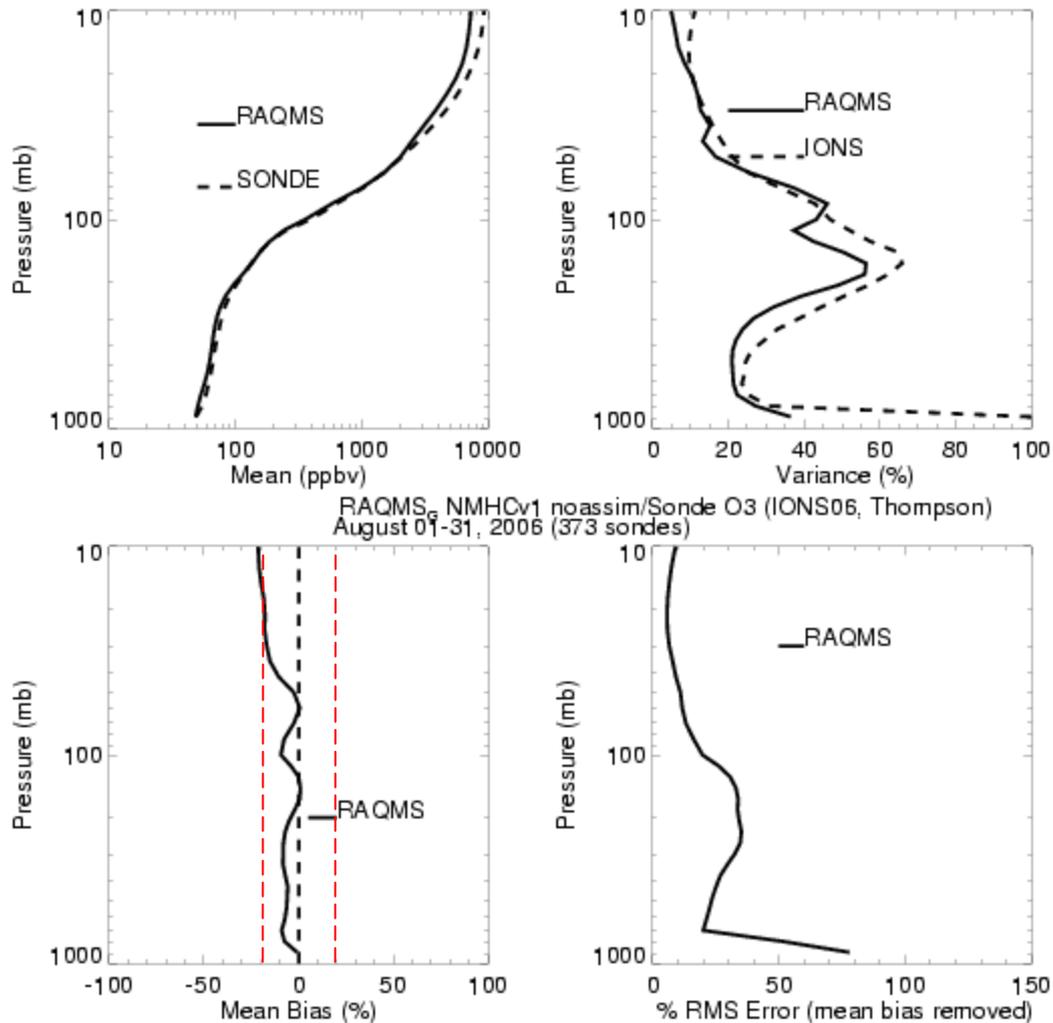
Tropospheric biases: < 10%
Stratospheric biases: -20%

August 2006 OSIRIS Assim-NO ASSIM Zonal mean Delta CO/O3 (July 15, 2006 OMI+TES IC)



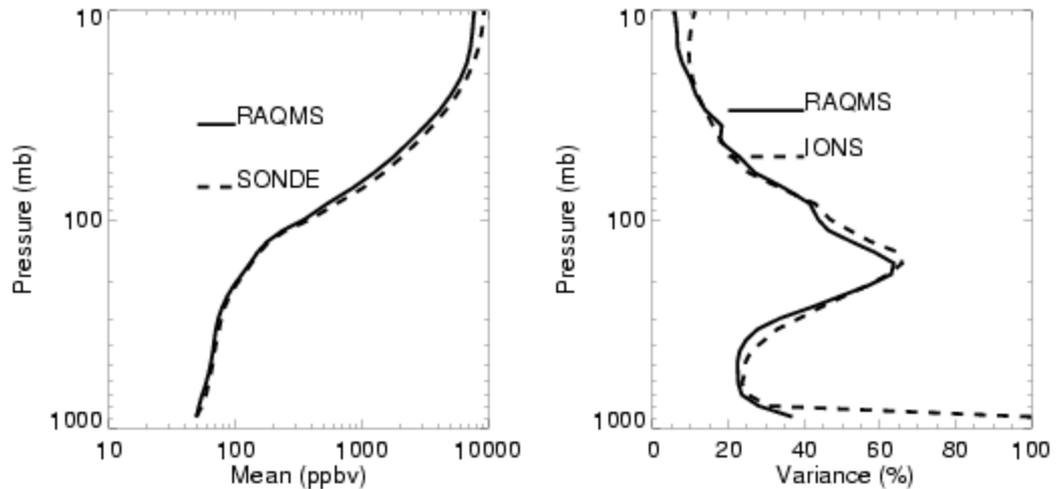
Note Change in Scale!

August 2006 NO ASSIM vs IONS (July 15, 2006 OMI+TES IC)

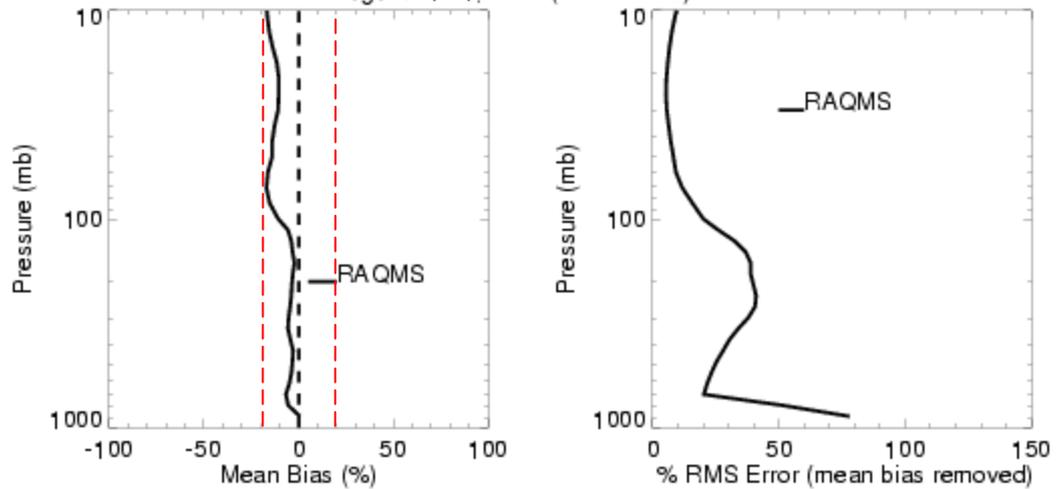


Tropospheric biases: -10%
Stratospheric biases: -20%

August 2006 OSIRIS ASSIM vs IONS (July 15, 2006 OMI+TES IC)



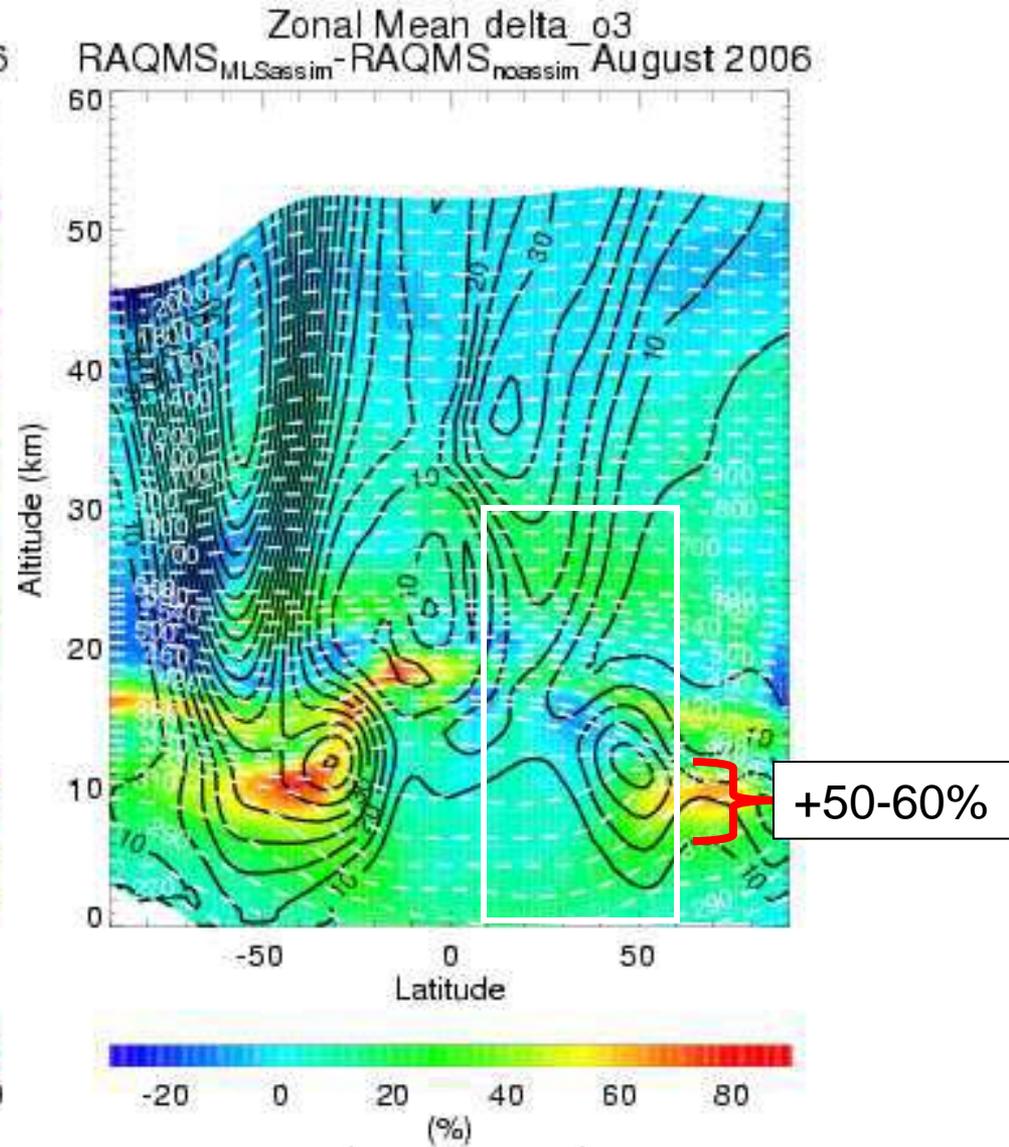
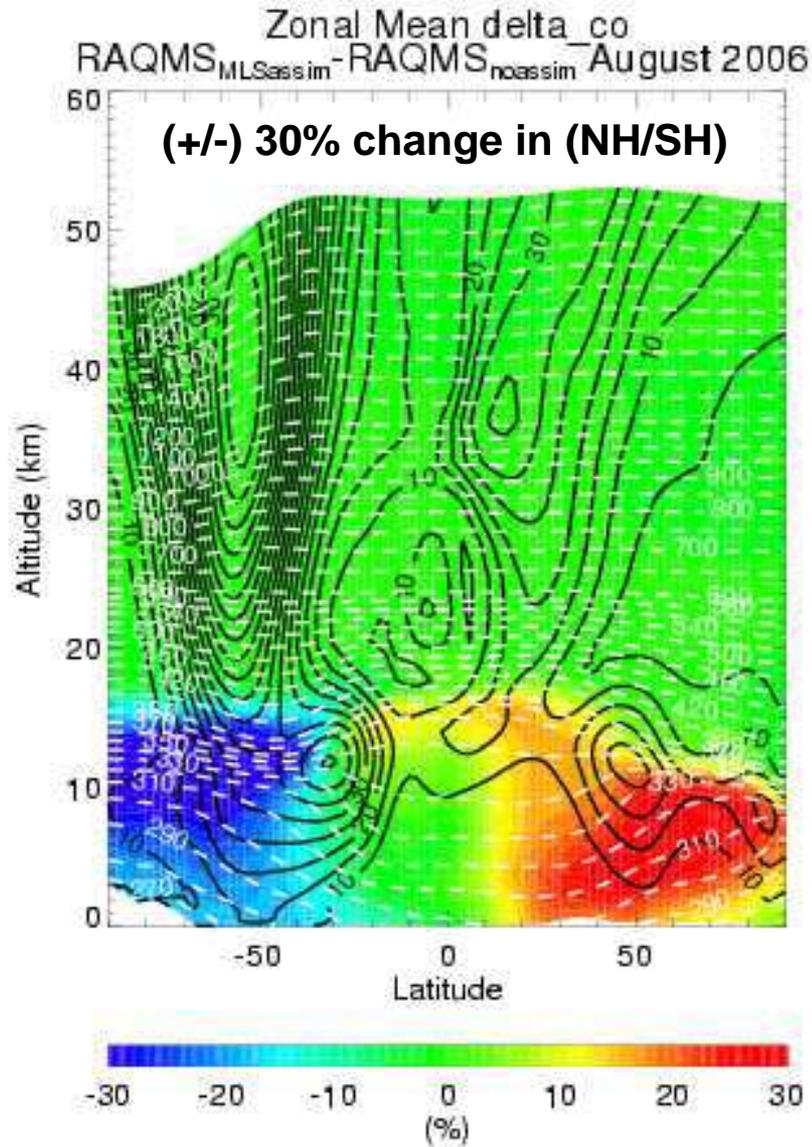
RAQMS, NMHCv1 OSIRIS 10 deg assim/Sonde O3 (IONS06, Thor August 01-31, 2006 (373 sondes))



Tropospheric biases: < 10%

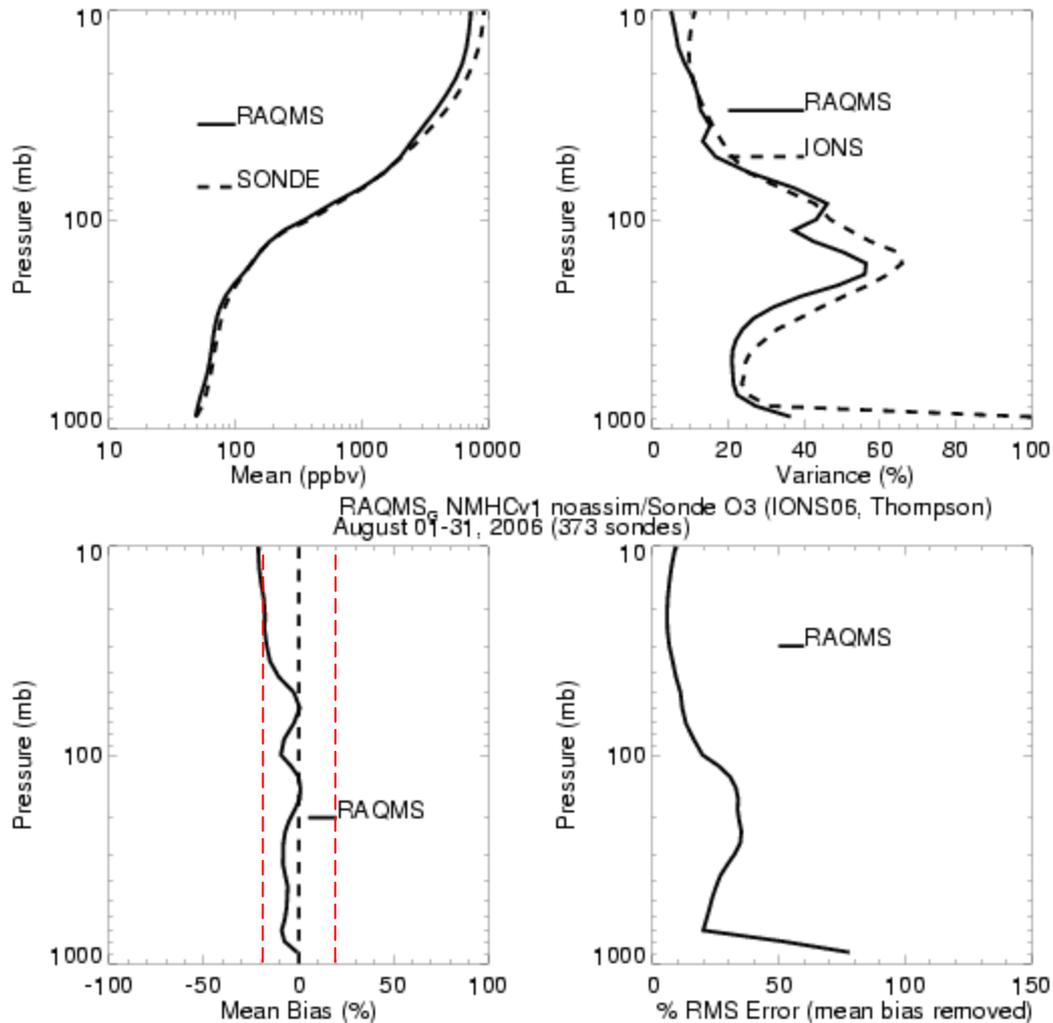
Lower Stratospheric biases: - 20%

August 2006 MLS Assim-NO ASSIM Zonal mean Delta CO/O3 (July 15, 2006 OMI+TES IC)



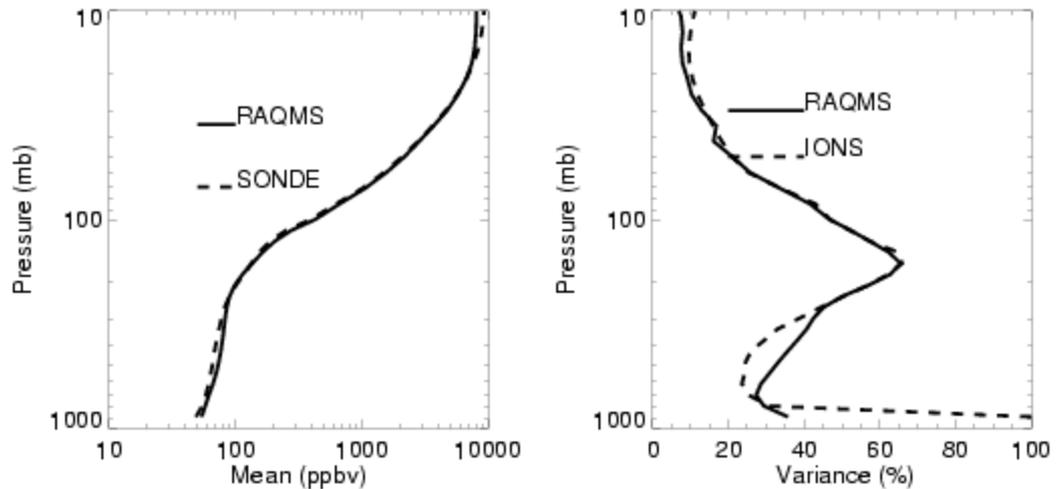
Note Change in Scale!

August 2006 NO ASSIM vs IONS (July 15, 2006 OMI+TES IC)

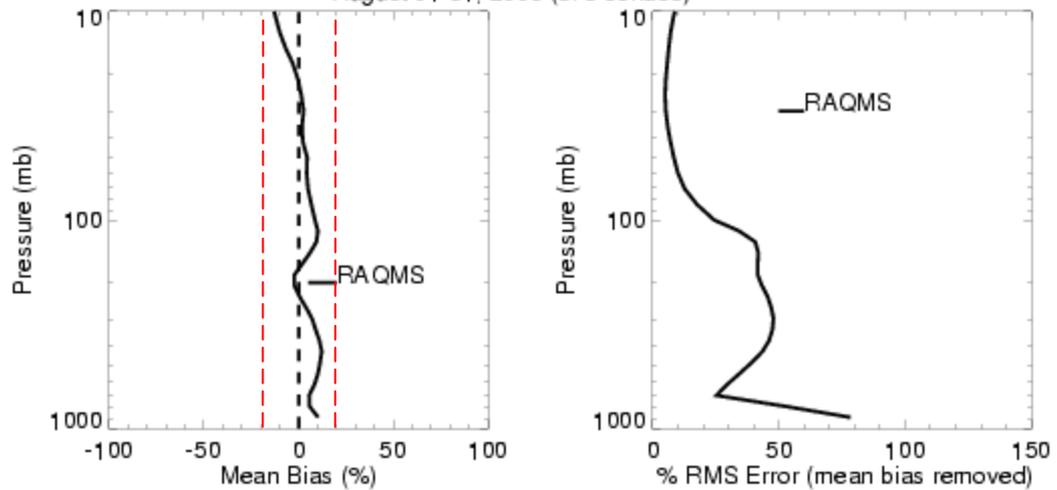


Tropospheric biases: -10%
Stratospheric biases: -20%

August 2006 MLS ASSIM vs IONS (July 15, 2006 OMI+TES IC)

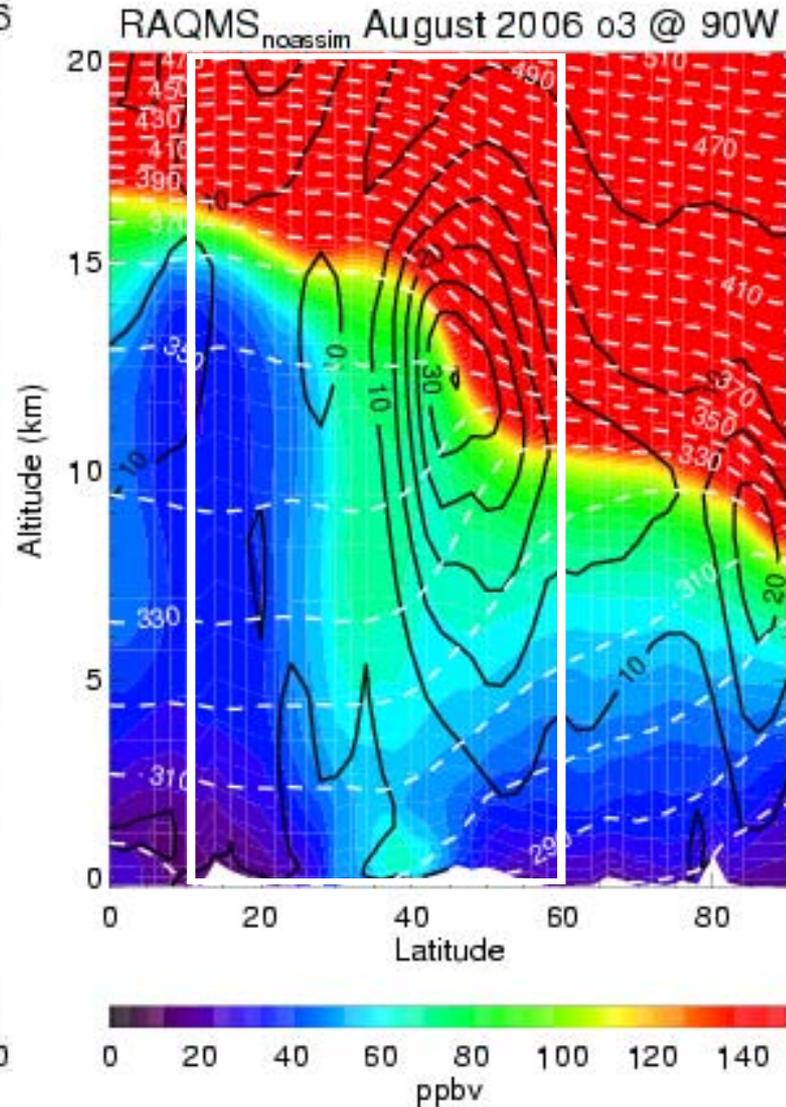
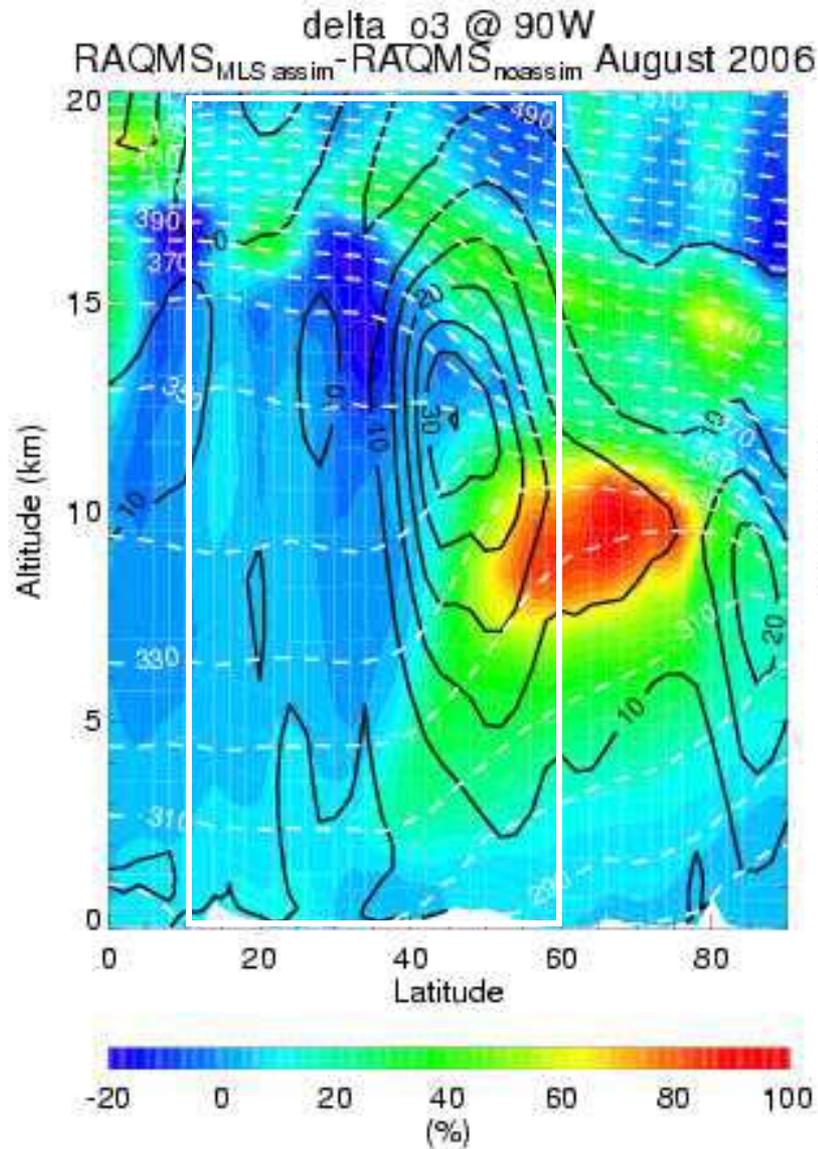


RAQMS, NMHCv1 MLS 10 deg assim/Sonde O3 (IONS06, Thomps)
August 01-31, 2006 (373 sondes)

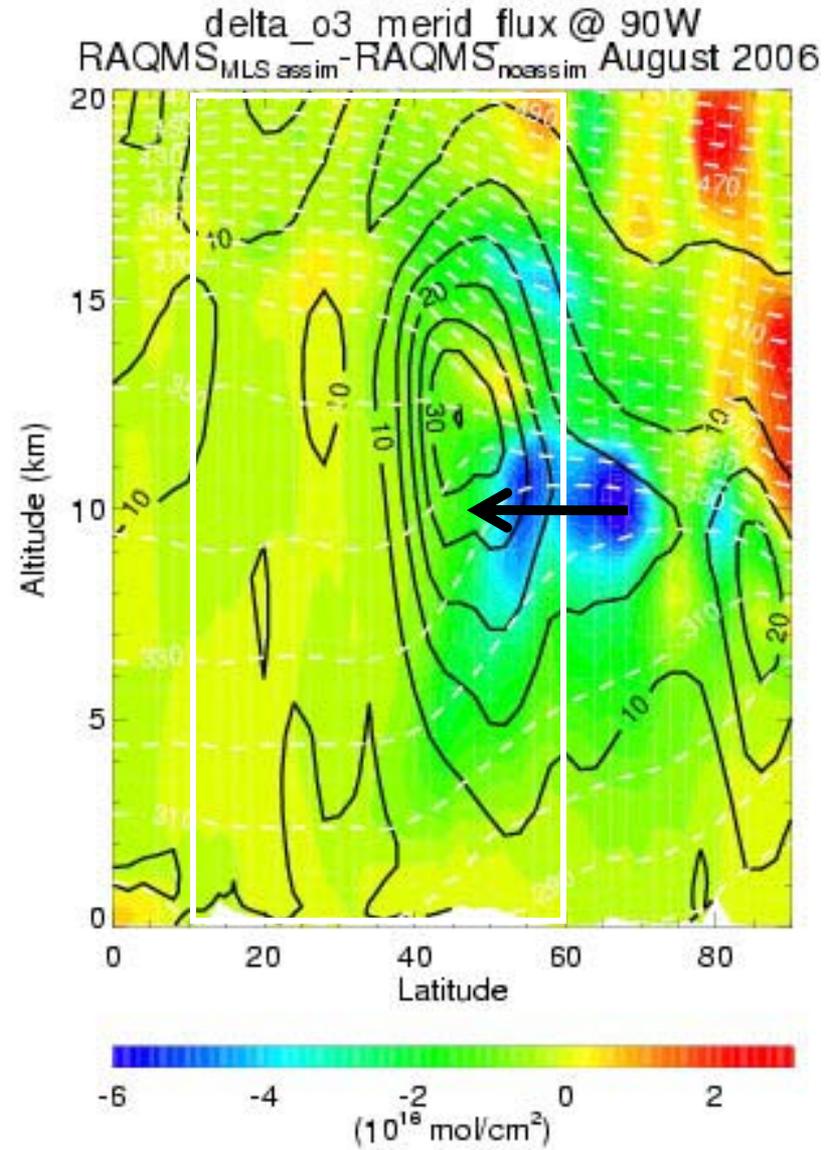
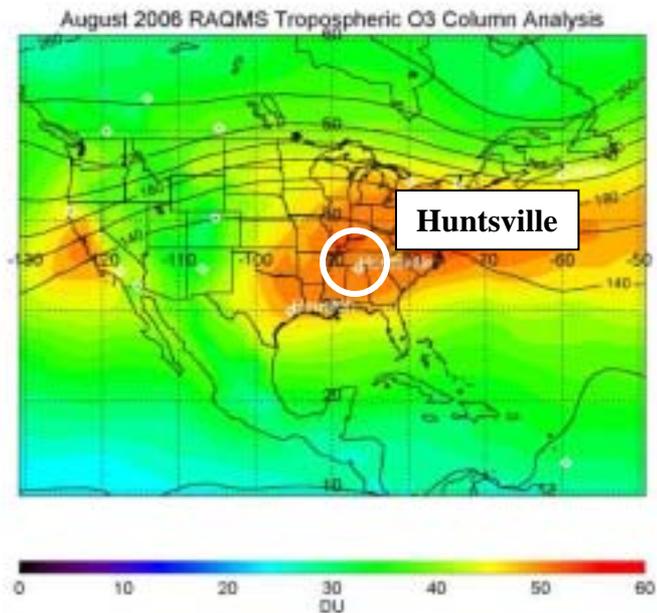
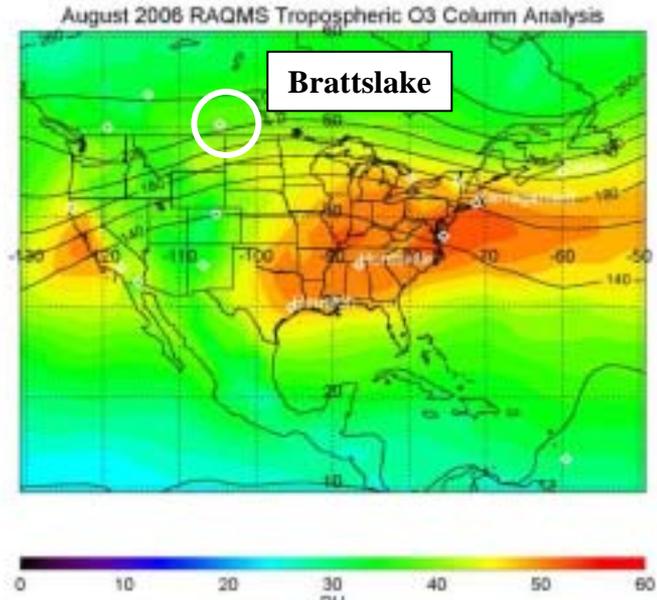


Tropospheric biases: +10%
Stratospheric biases: <10%

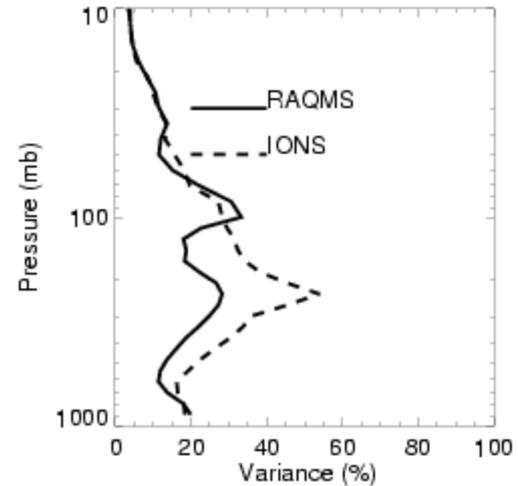
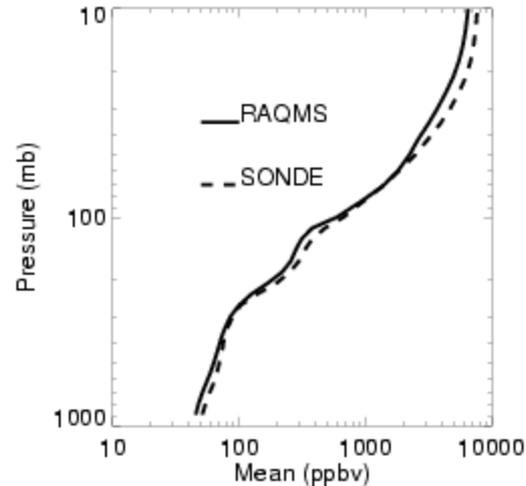
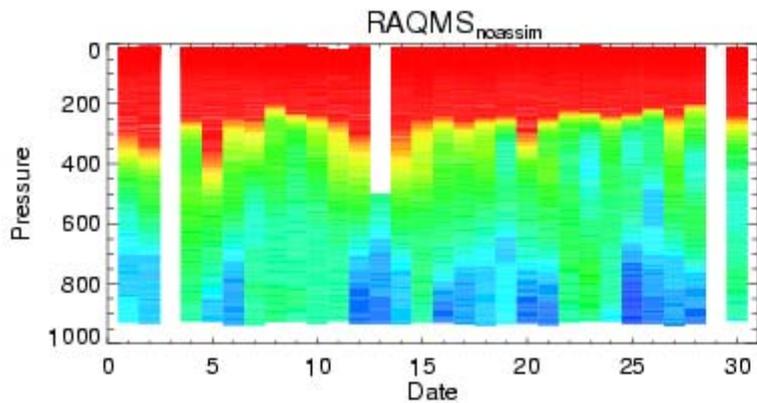
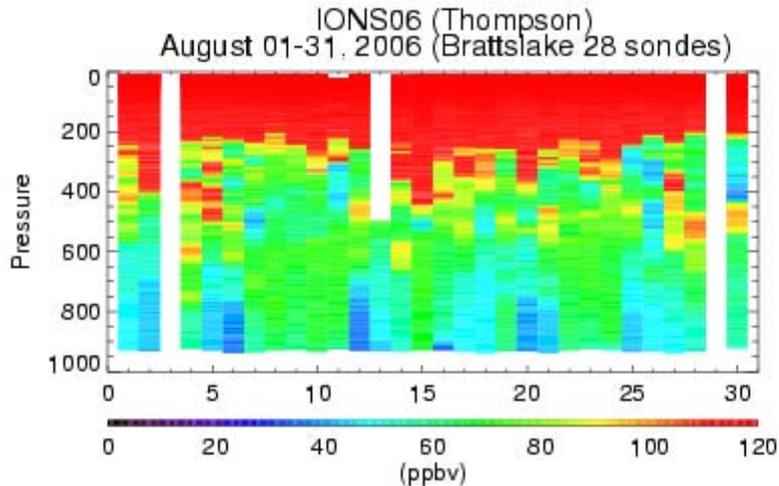
August 2006 MLS Assim-NO ASSIM mean and Delta O3 @ 90W (July 15, 2006 OMI+TES IC)



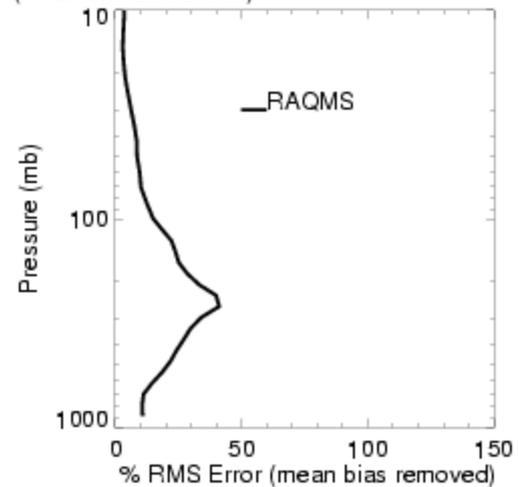
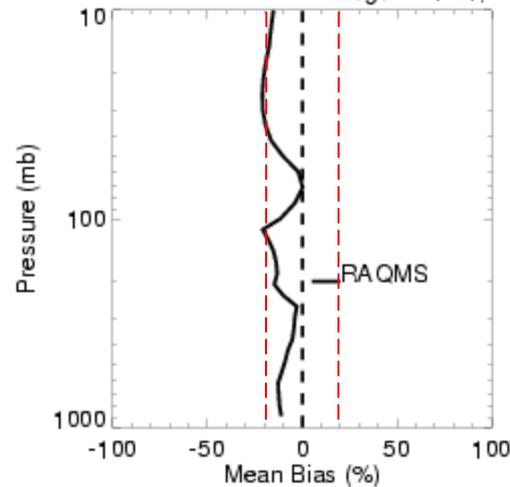
August 2006 MLS Assim-NO ASSIM Delta O3 Flux @ 90W (July 15, 2006 OMI+TES IC)



Bratts Lake Saskatchewan (50.2N) Timeseries/Statistics (RAQMS No ASSIM)

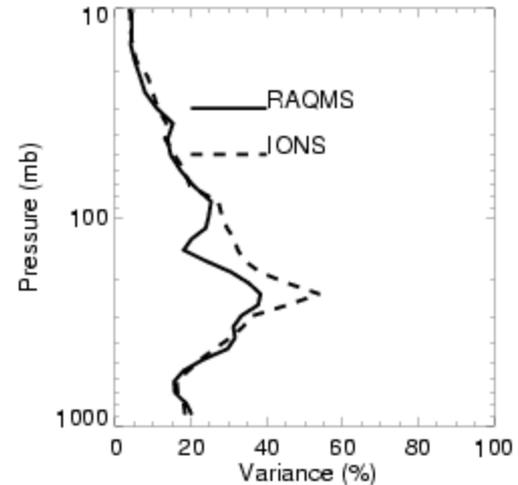
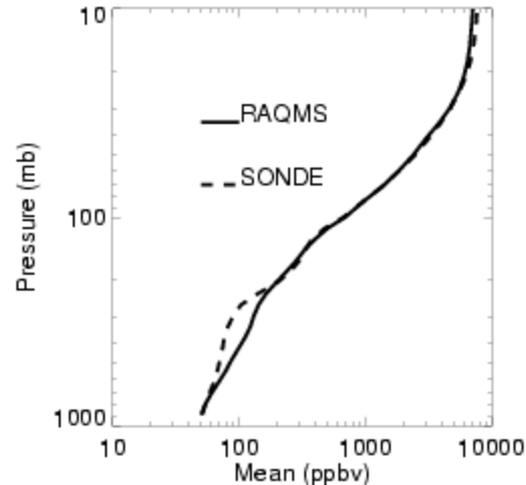
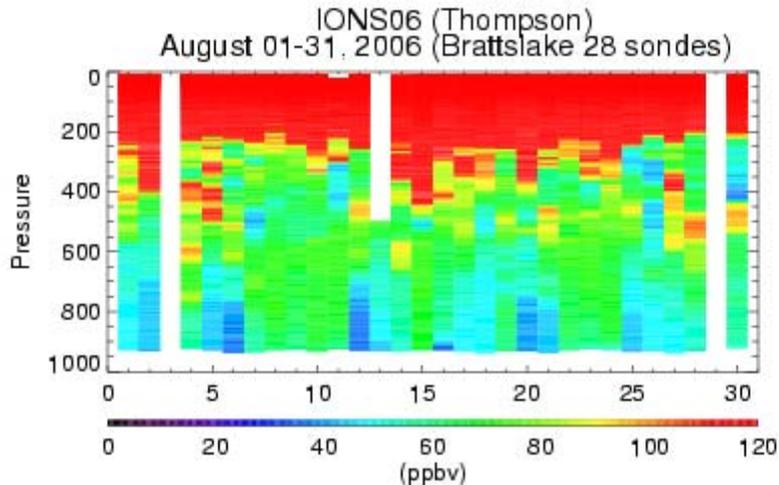


RAQMS_{noassim}/Sonde O3 (IONS06, Thompson)
August 01-31, 2006 (Brattslake 28 sondes)

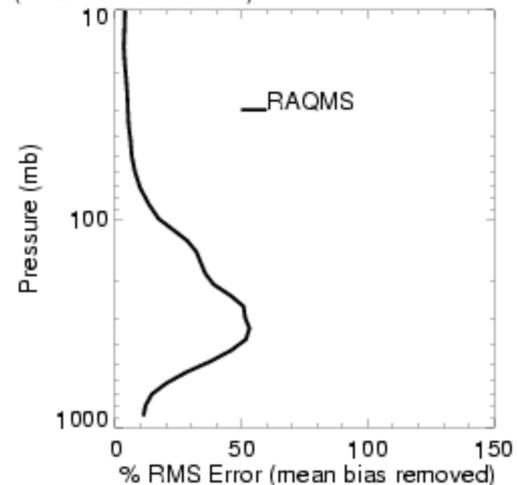
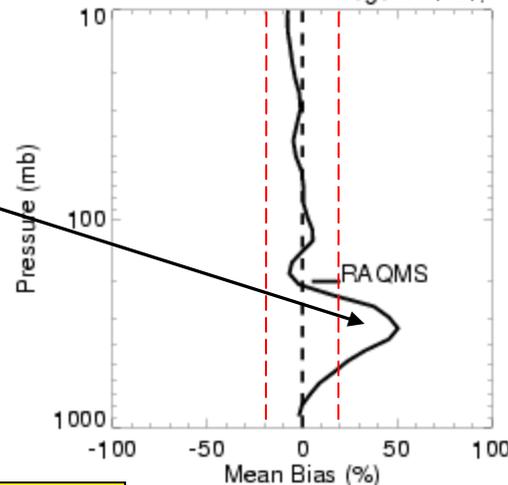
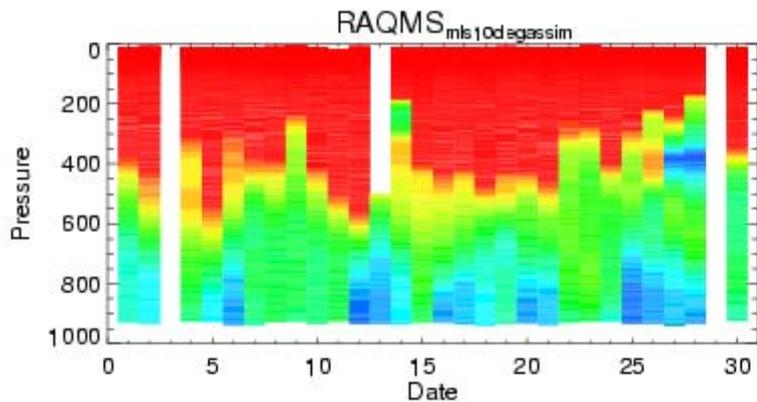


Tropospheric/Stratospheric biases: - 20%

Bratts Lake Saskatchewan (50.2N) Timeseries/Statistics (RAQMS MLS ASSIM)



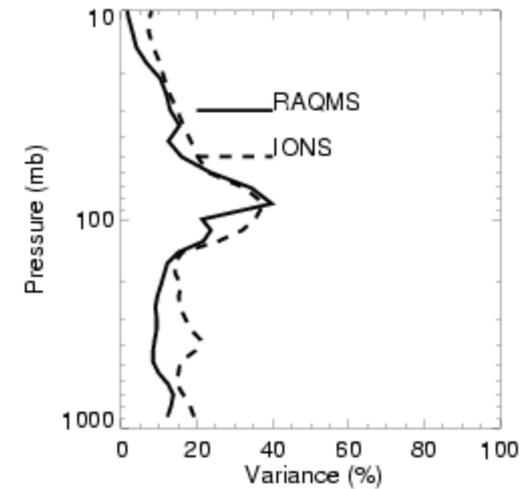
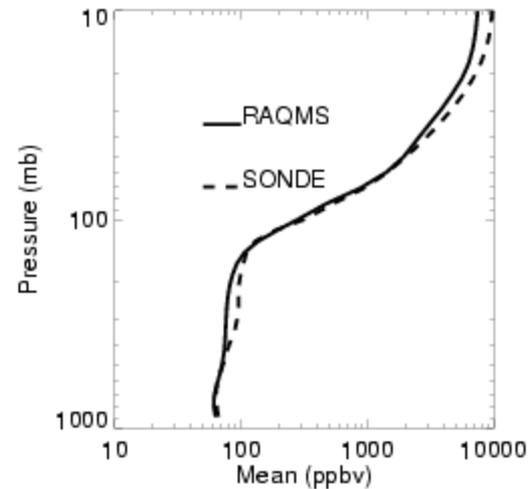
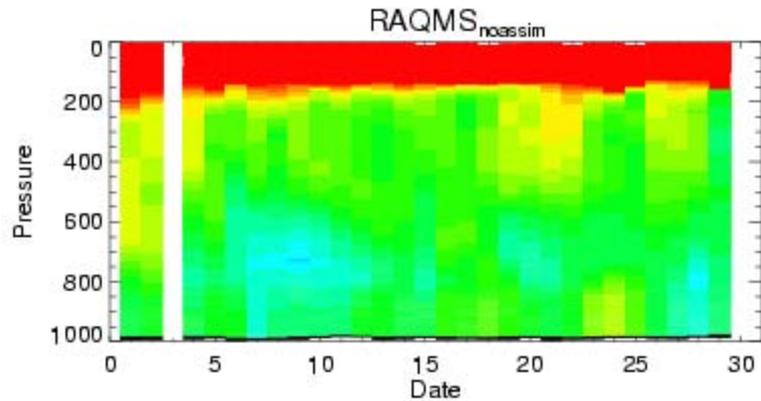
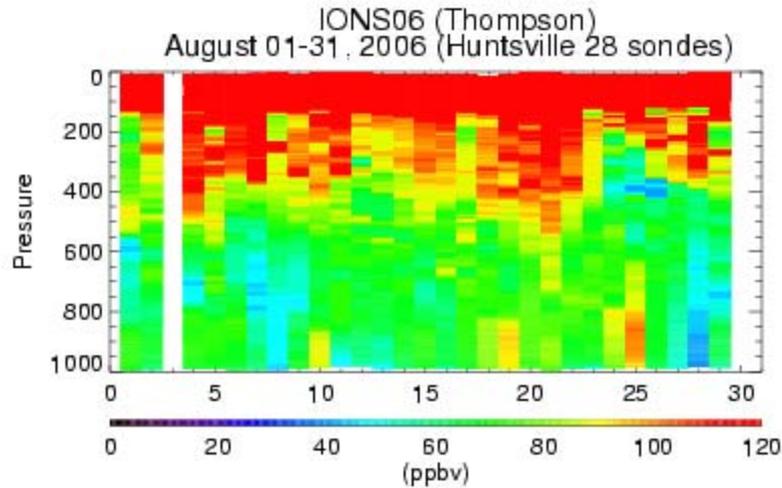
RAQMS_{mls10degassim} / Sonde O3 (IONS06, Thompson)
August 01-31, 2006 (Brattslake 28 sondes)



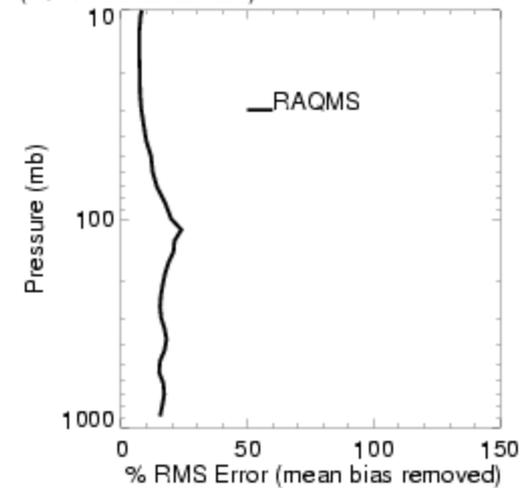
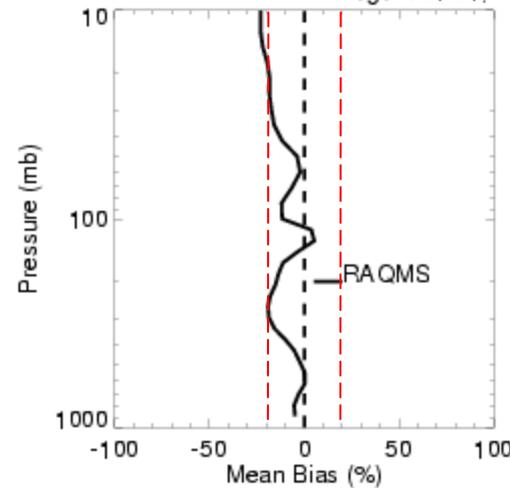
Reduced bias above 100mb
Large increases in upper tropospheric O3

Stratospheric biases: <10%
Tropospheric biases: +50%

Huntsville, AL (34.73N) Timeseries/Statistics (RAQMS No ASSIM)

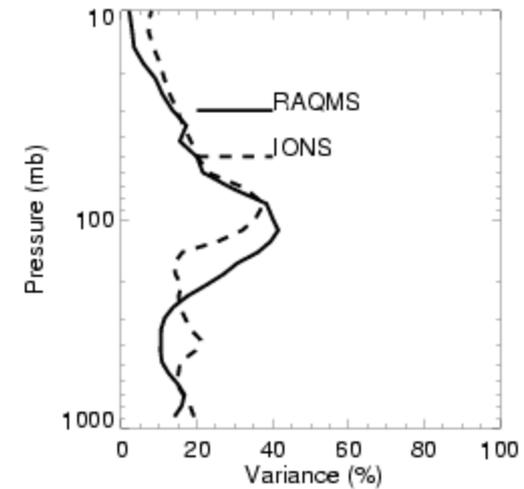
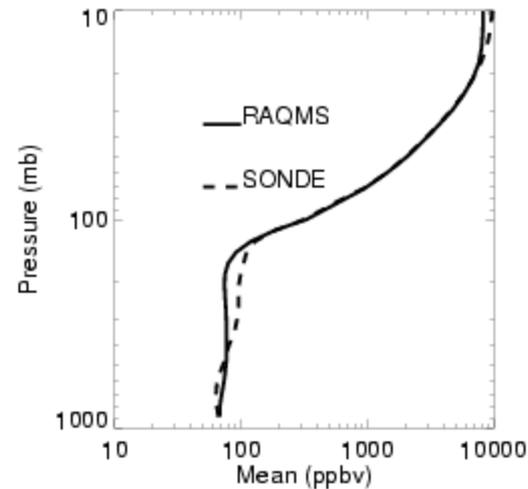
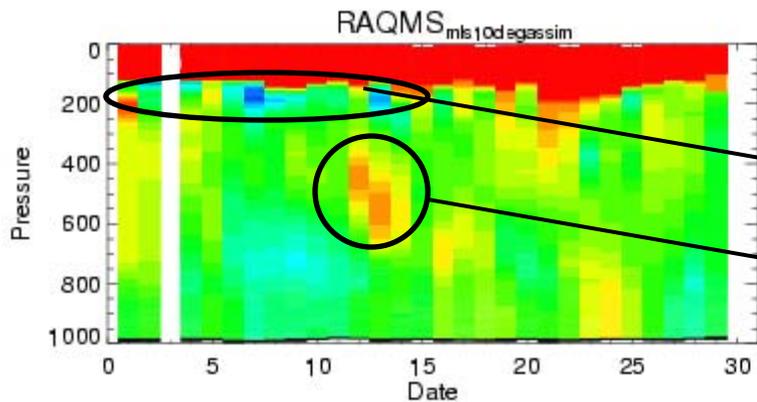
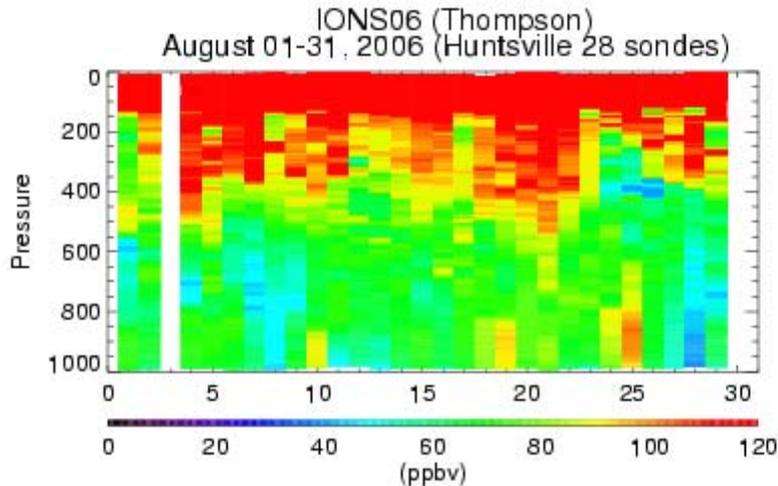


RAQMS_{noassim}/Sonde O3 (IONS06, Thompson)
August 01-31, 2006 (Huntsville 28 sondes)

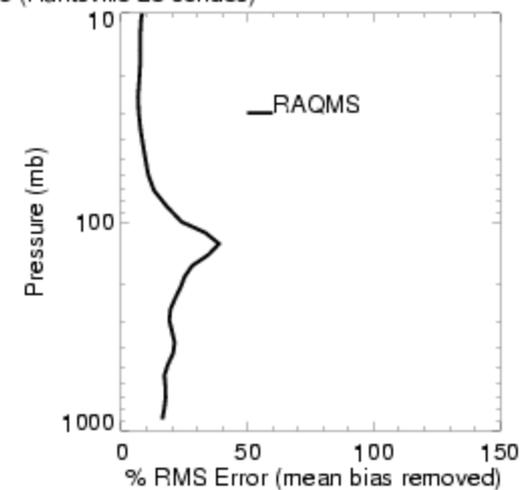
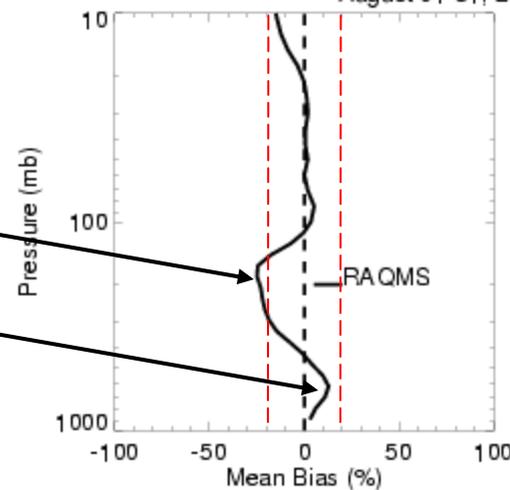


Tropospheric/Stratospheric biases: - 20%

Huntsville, AL (34.73N) Timeseries/Statistics (RAQMS MLS ASSIM)



RAQMS_{mls 10deg assim}/Sonde O3 (IONS06, Thompson)
August 01-31, 2006 (Huntsville 28 sondes)



Reduced bias above 100mb
Larger errors below 200mb

Stratospheric biases: <10%
Tropospheric biases: +/- 20%

Optimal combination:

MLS (above 100mb)

TES (below 100mb)

(based on single measurement Data Denial Studies)

Multi-sensor impact study:

MLS (above 100mb)

TES (below 100mb)

MODIS AM/PM AOD

Addition of Aerosol
Assimilation



Improved Baseline:

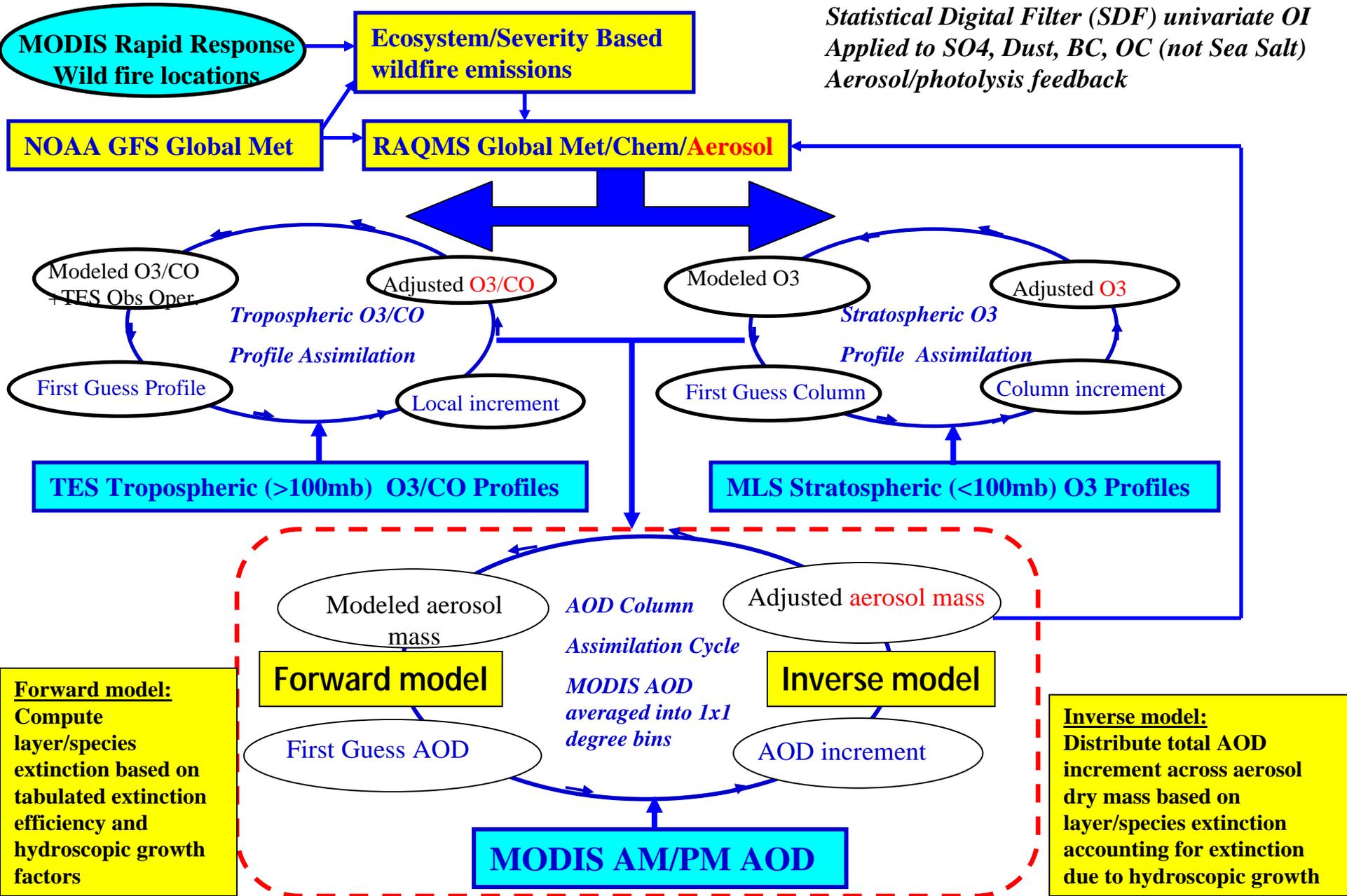
Corrected error in dz calculation (impacts emissions)

Improved tropical biomass burning estimates

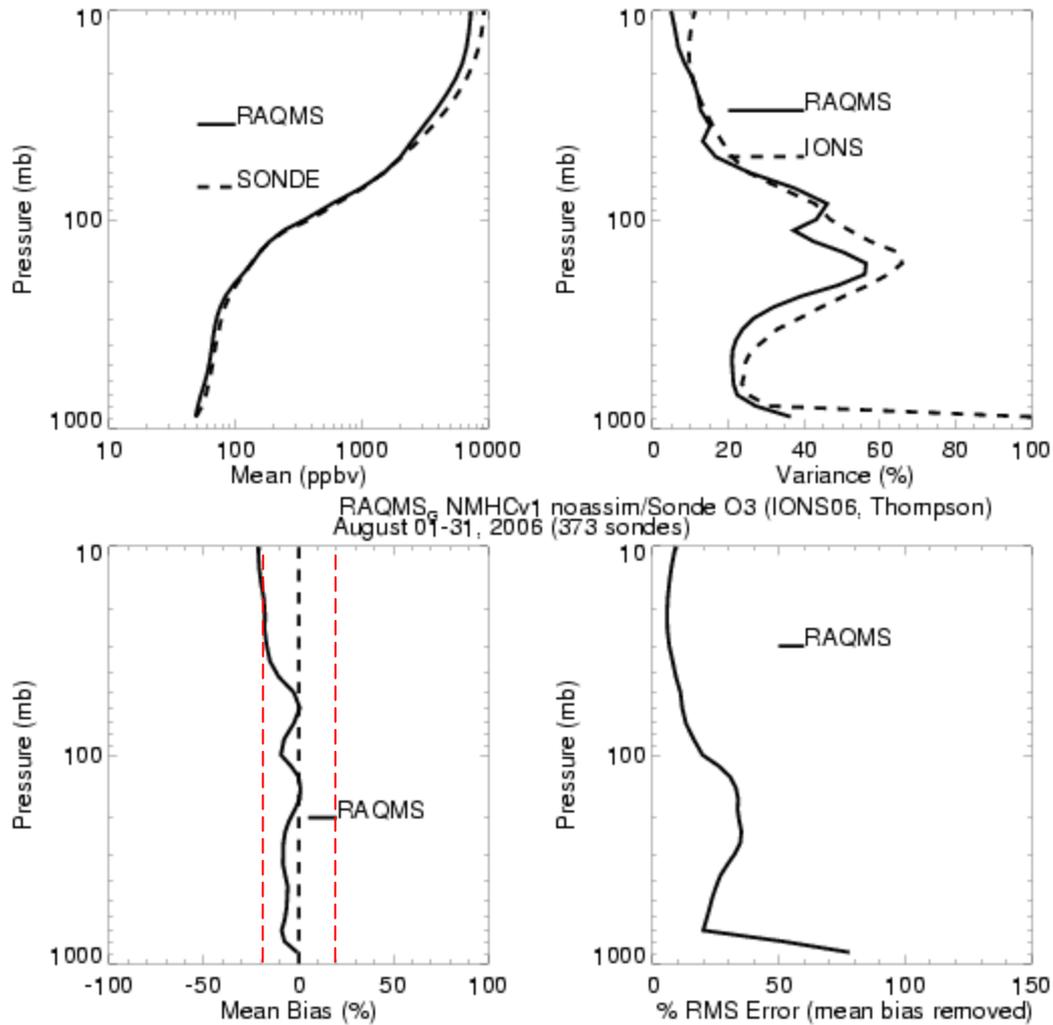
Aerosol influence on photoysis calculations (GOCART aerosols)

RAQMS_{global} (2x2) MLS/TES/MODIS Reanalysis O3/CO/AOD Assimilation Procedure

*2x2 degree Global online aerosol (GOCART)
Statistical Digital Filter (SDF) univariate OI
Applied to SO4, Dust, BC, OC (not Sea Salt)
Aerosol/photolysis feedback*

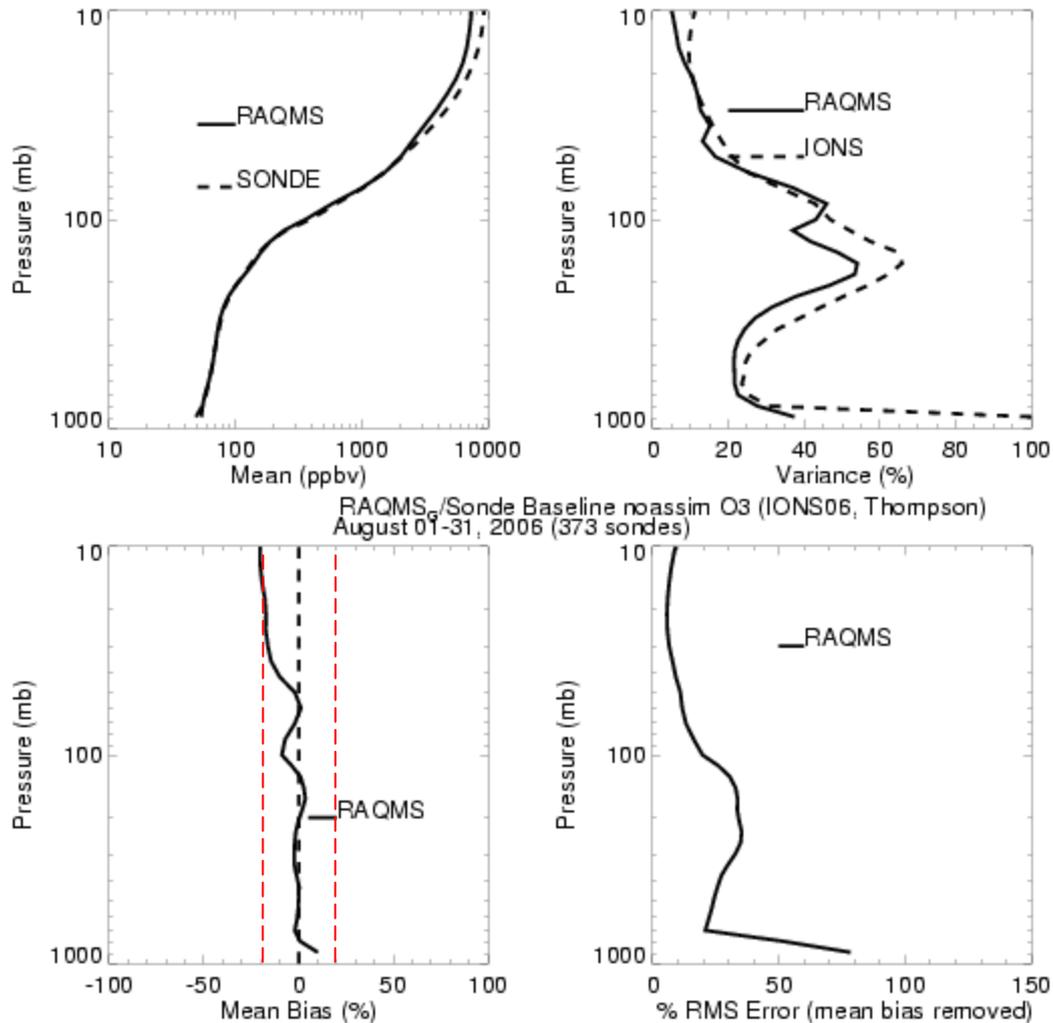


August 2006 NO ASSIM vs IONS (July 15, 2006 OMI+TES IC)



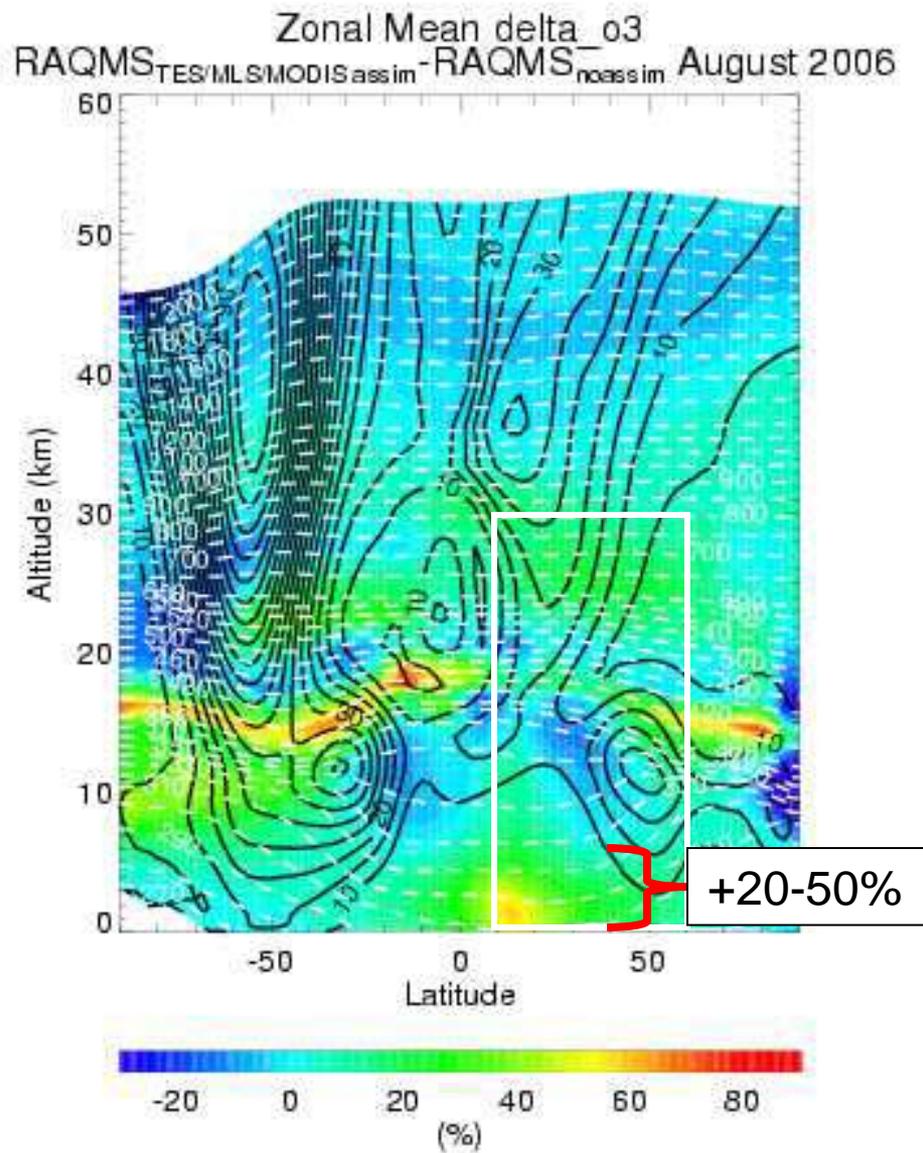
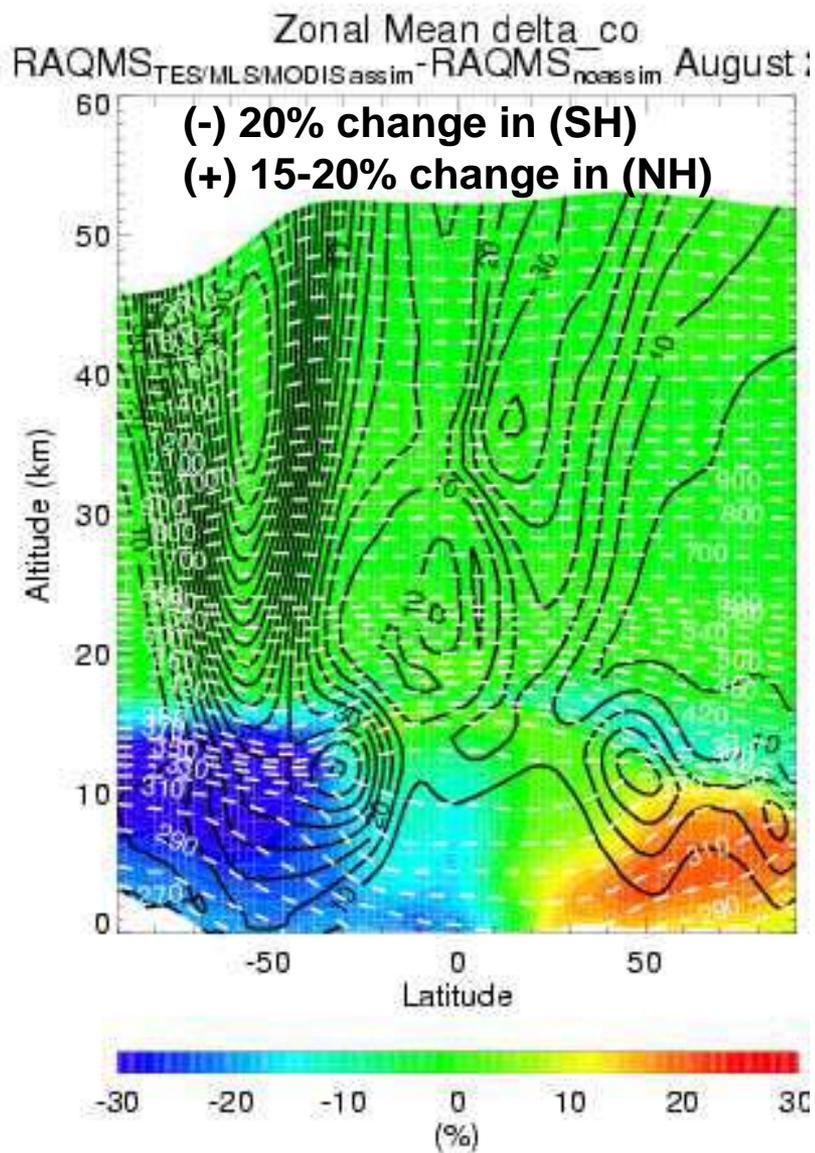
Tropospheric biases: -10%

August 2006 New Baseline NO ASSIM vs IONS (July 15, 2006 OMI+TES IC)

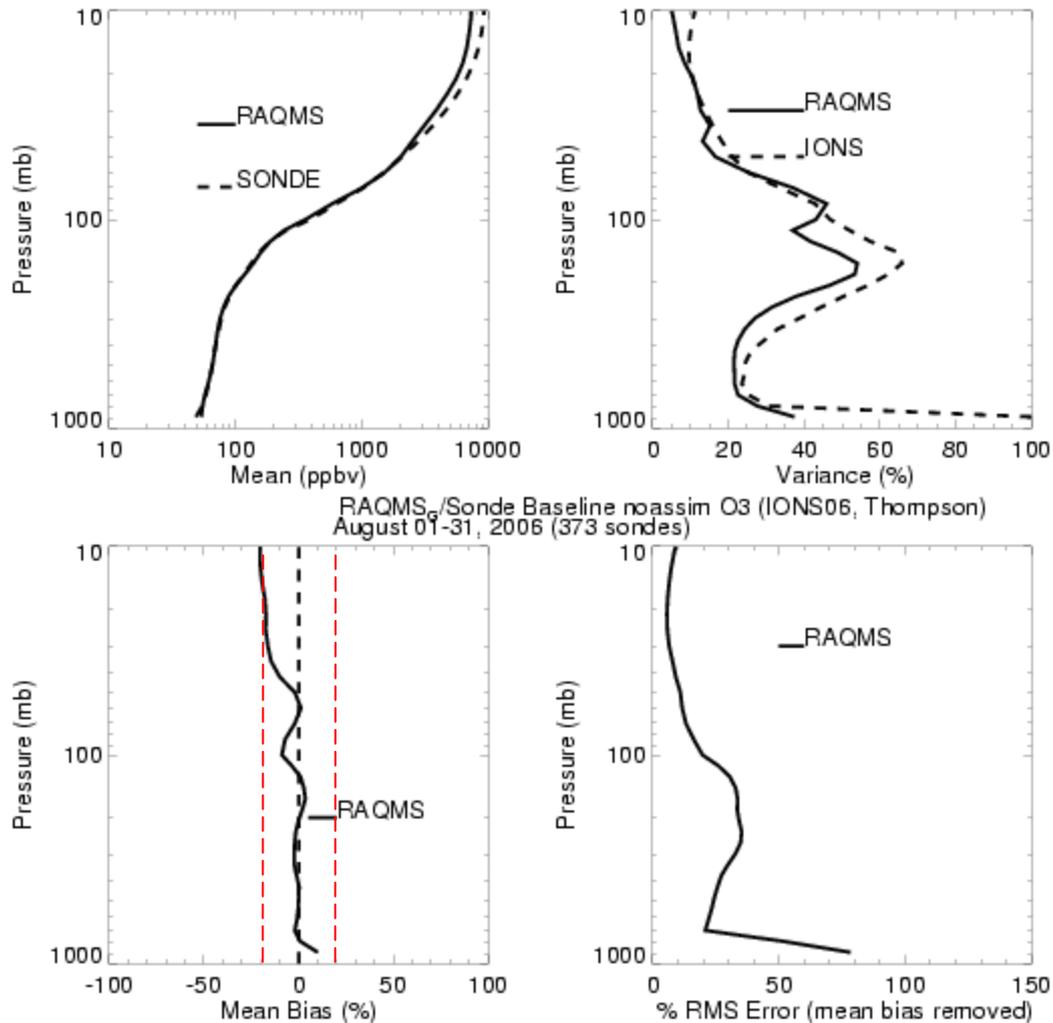


Tropospheric biases: <10%
Stratospheric biases: -20%

August 2006 TES/MLS/MODIS - NO ASSIM Zonal mean Delta CO/O3 (July 15, 2006 OMI+TES IC)

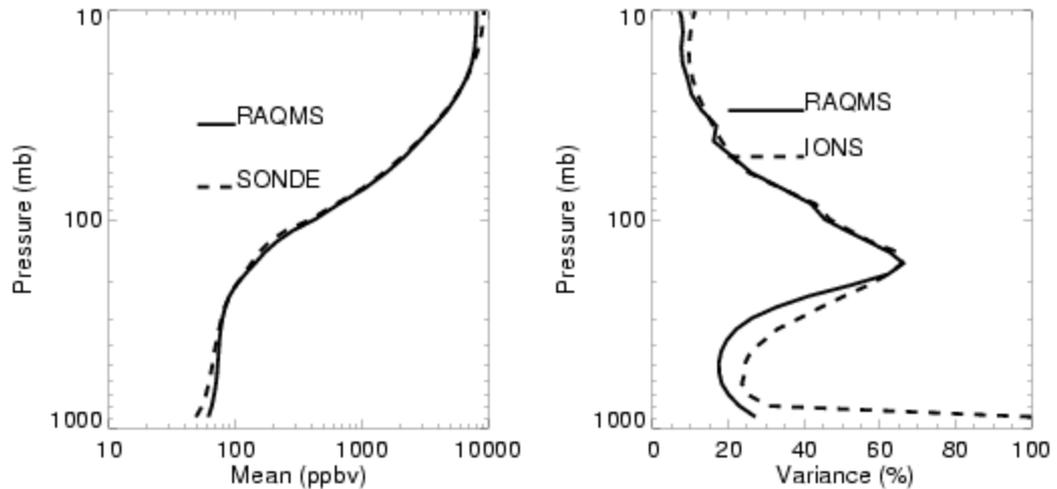


August 2006 New Baseline NO ASSIM vs IONS (July 15, 2006 OMI+TES IC)



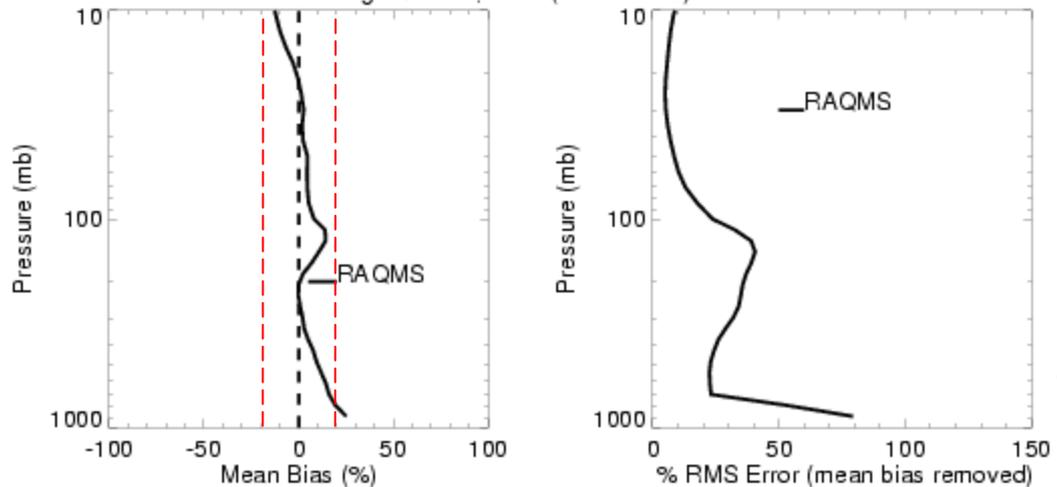
Tropospheric biases: <10%
Stratospheric biases: -20%

August 2006 TES/MLS/MODIS ASSIM vs IONS (July 15, 2006 OMI+TES IC)



Improved Variance

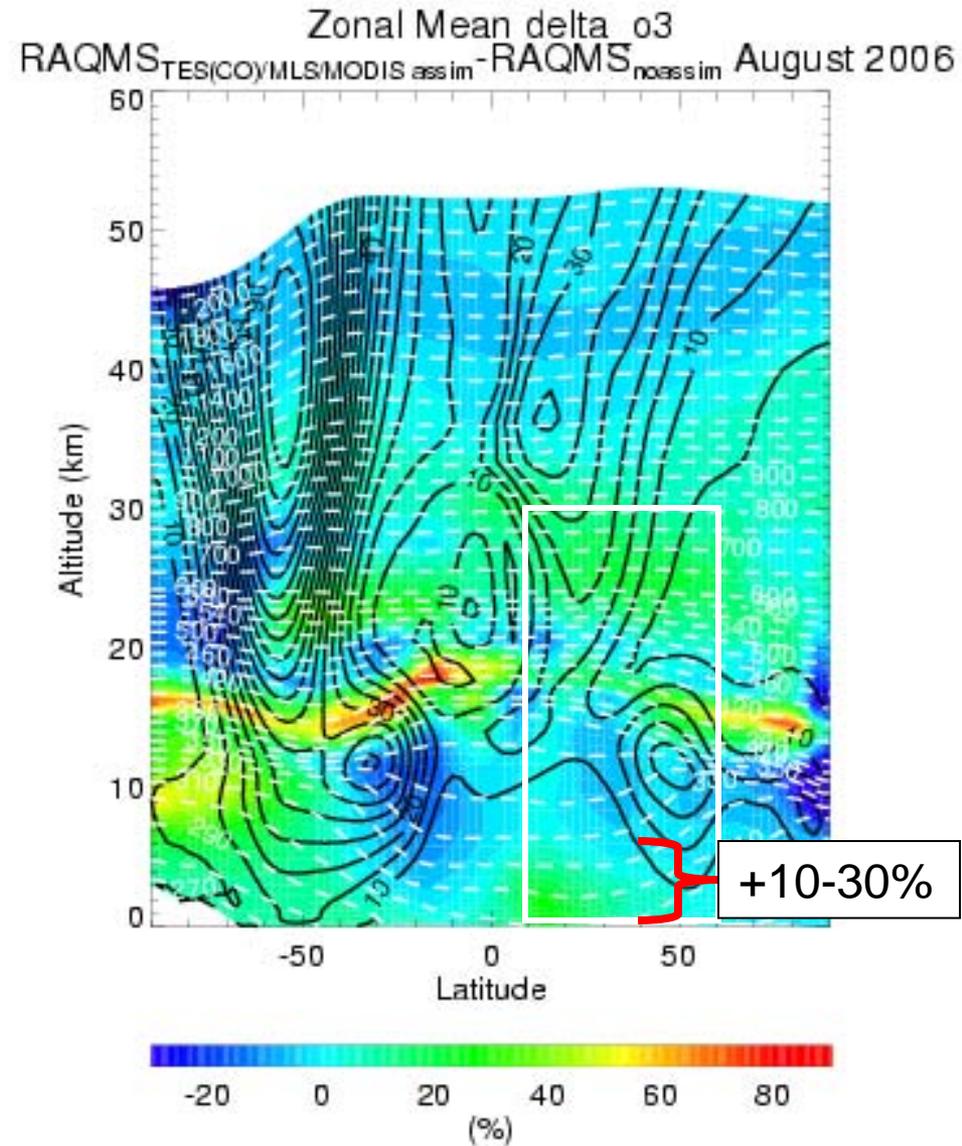
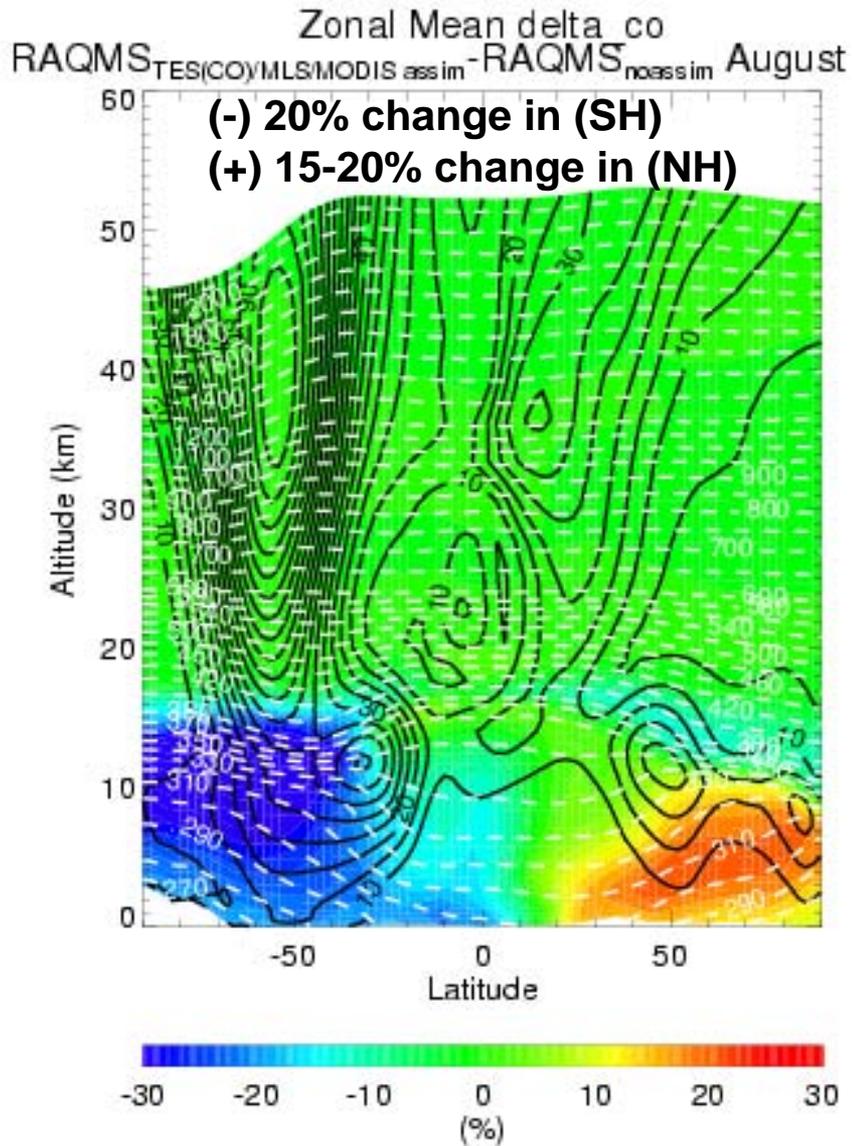
RAQMS/Sonde Baseline TES/MLS/MODIS assim O3 (IONS06, The August 01-31, 2006 (373 sondes))



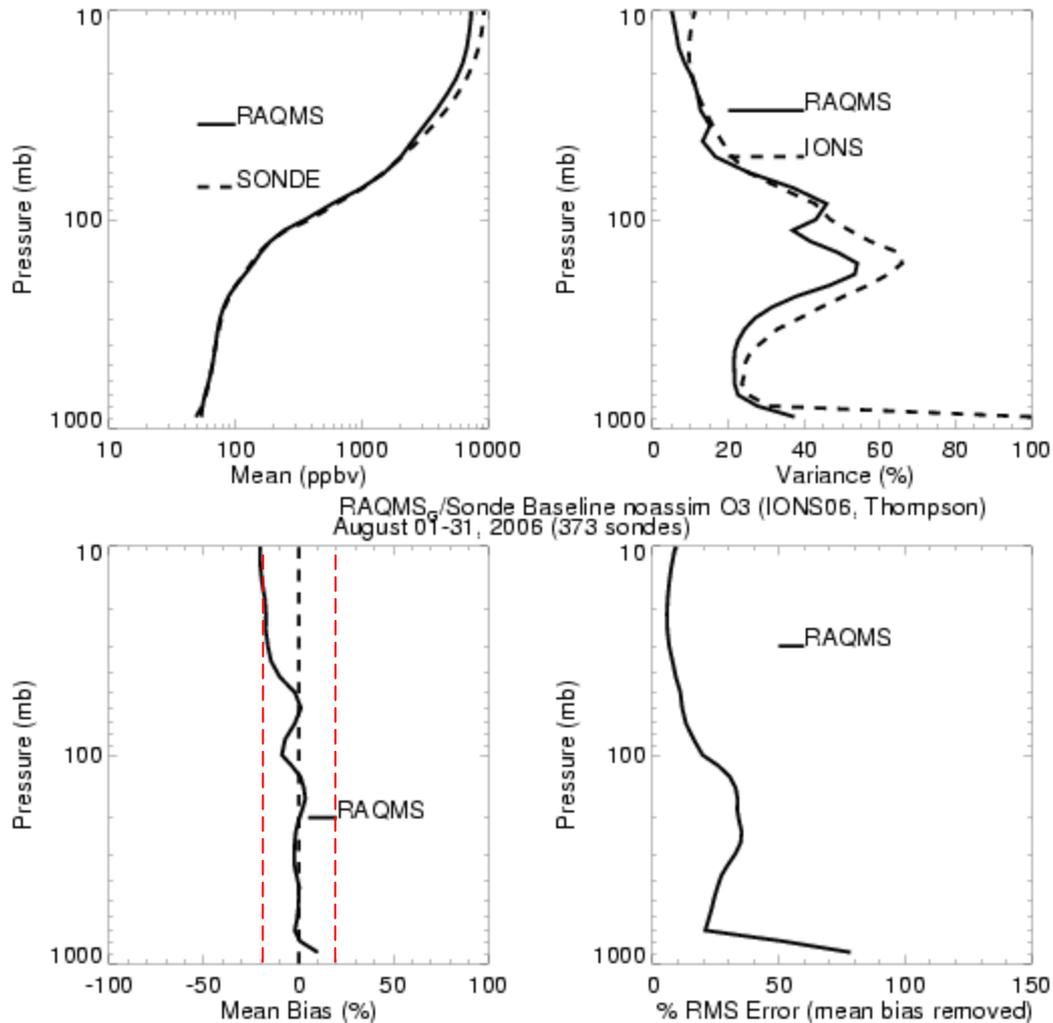
Introduces lower troposphere high bias

Lower Tropospheric biases: +20%
Stratospheric biases: <10%

August 2006 TESCO/MLS/MODIS-NO ASSIM Zonal mean Delta CO/O3 (July 15, 2006 OMI+TES IC)

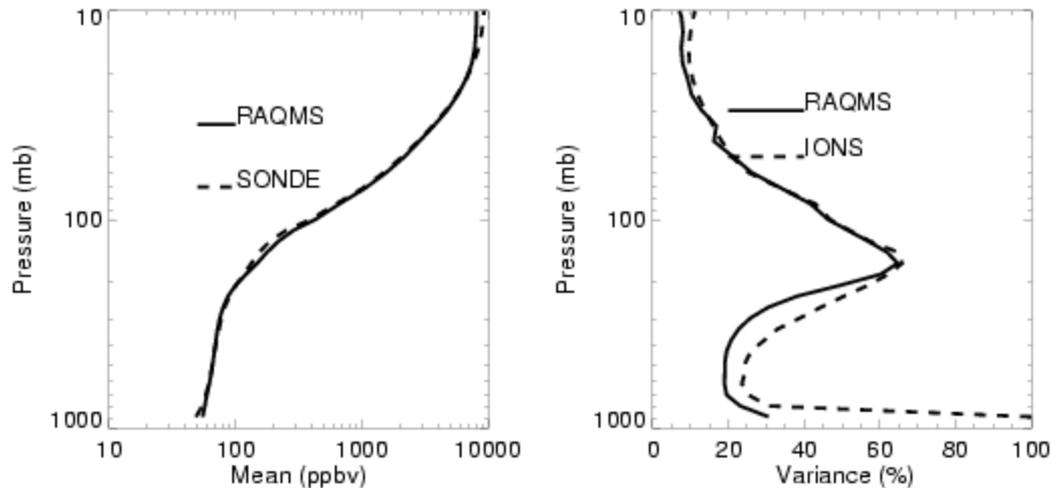


August 2006 New Baseline NO ASSIM vs IONS (July 15, 2006 OMI+TES IC)



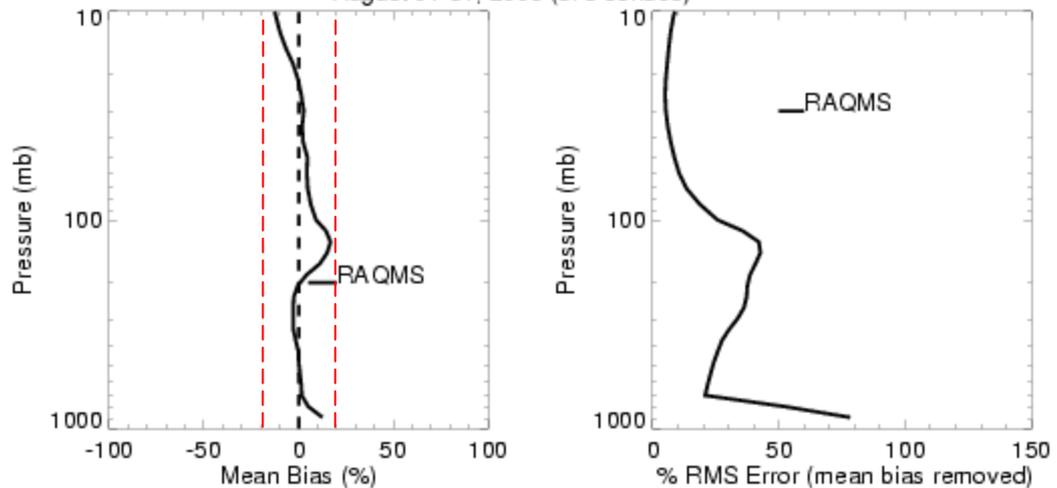
Tropospheric biases: <10%
Stratospheric biases: -20%

August 2006 TES (CO)/MLS/O3/MODIS ASSIM vs IONS (July 15, 2006 OMI+TES IC)



Improved Variance

RAQMS_g/Sonde TES CO/MLS O3/MODIS AOS assim O3 (IONS06, August 01-31, 2006 (373 sondes))



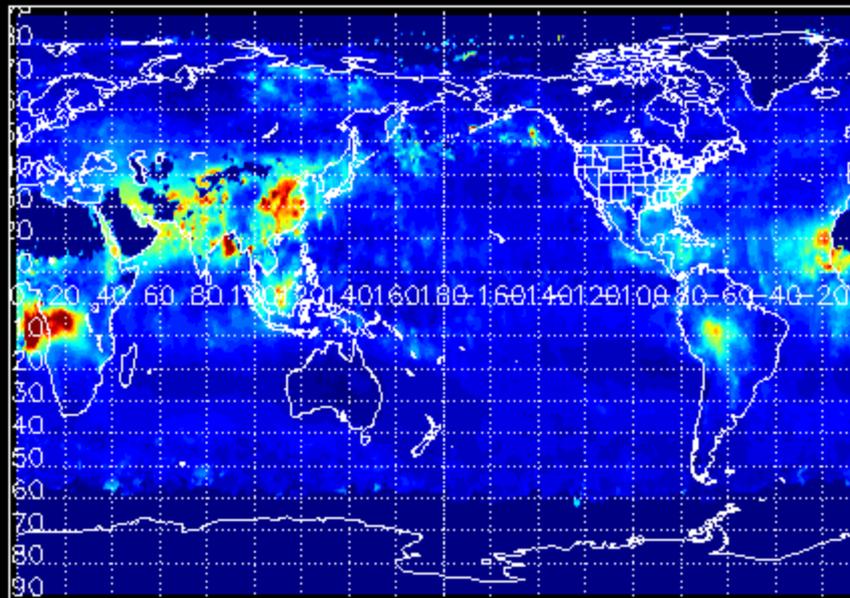
Tropospheric biases: <10%

Stratospheric biases: <10%

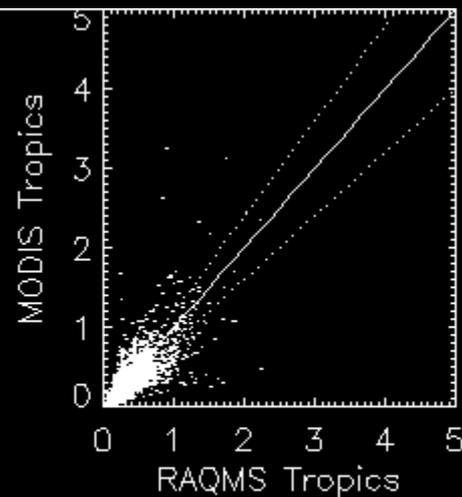
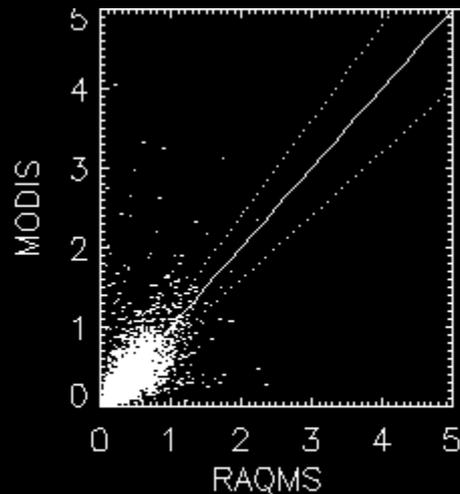
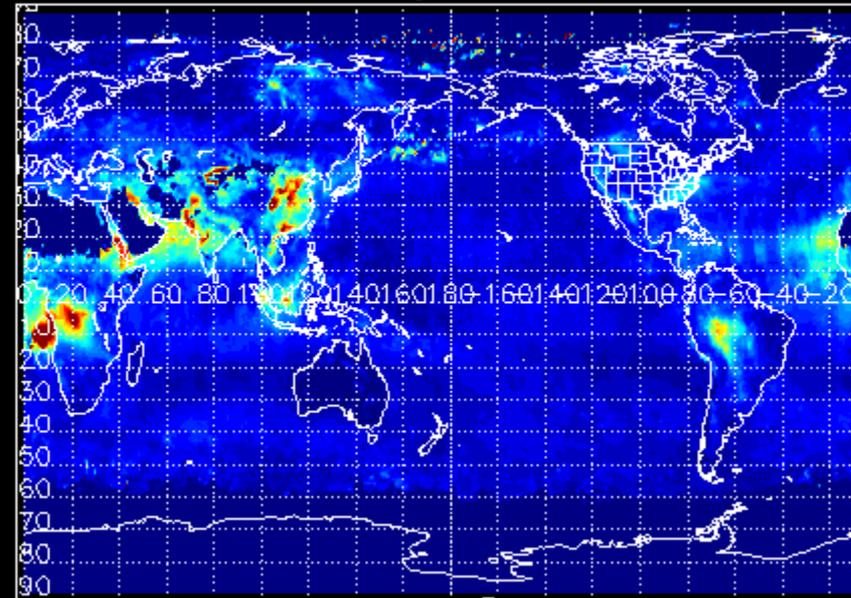
Tropopause biases: +20%

RAQMS (6hr FX) vs MODIS August 2006 Monthly Mean AOD

RAQMS AOD (TES/MLS/MODIS Assim)
August 01-31, 2006

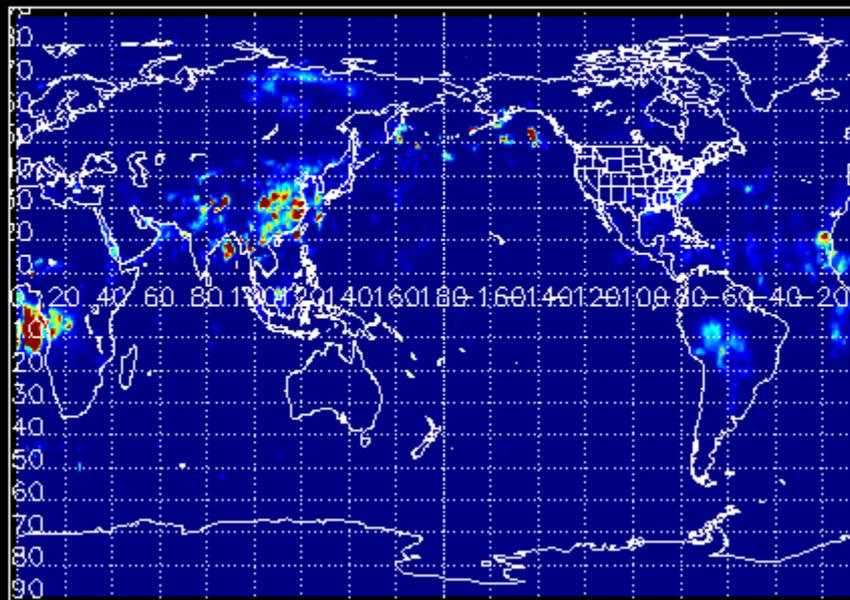


MODIS AOD August 01-31, 2006

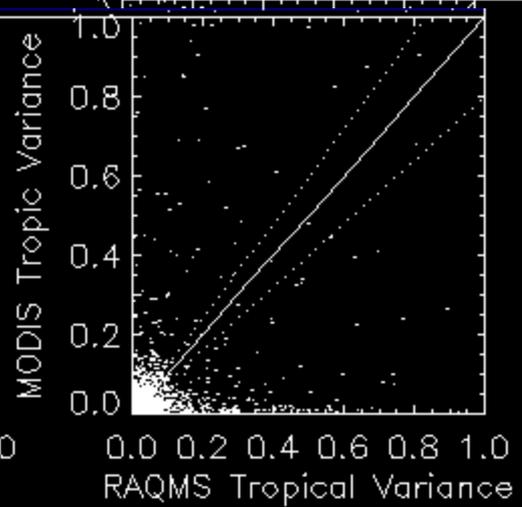
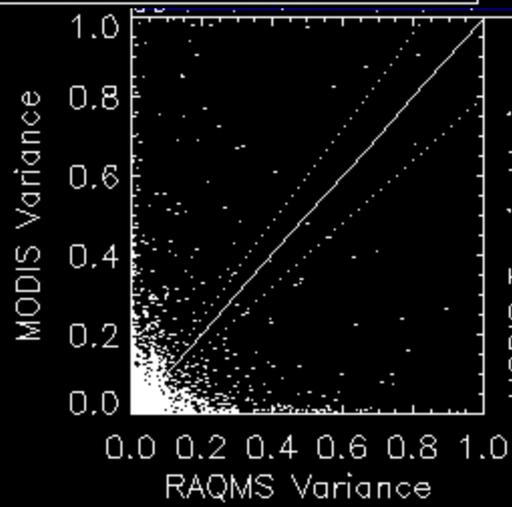
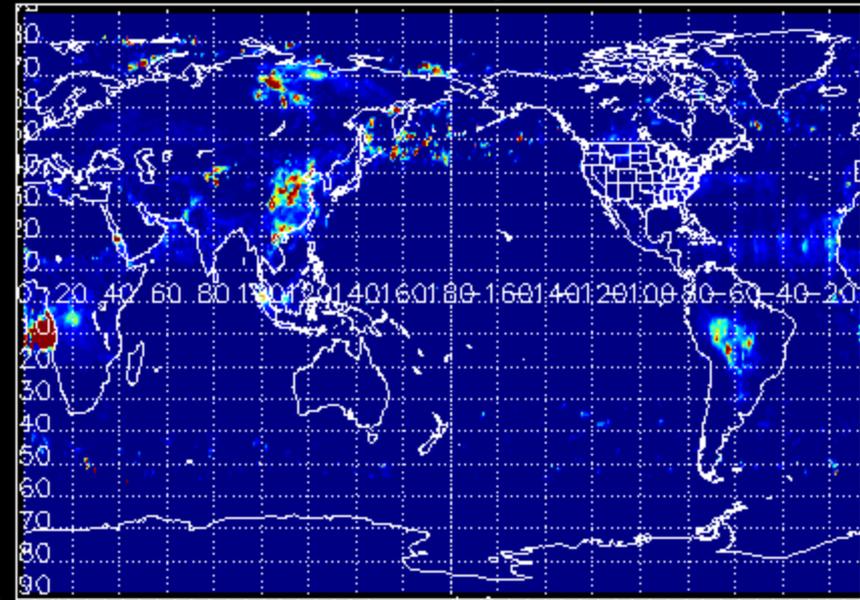


RAQMS (6hr FX) vs MODIS August 2006 Monthly AOD Variance

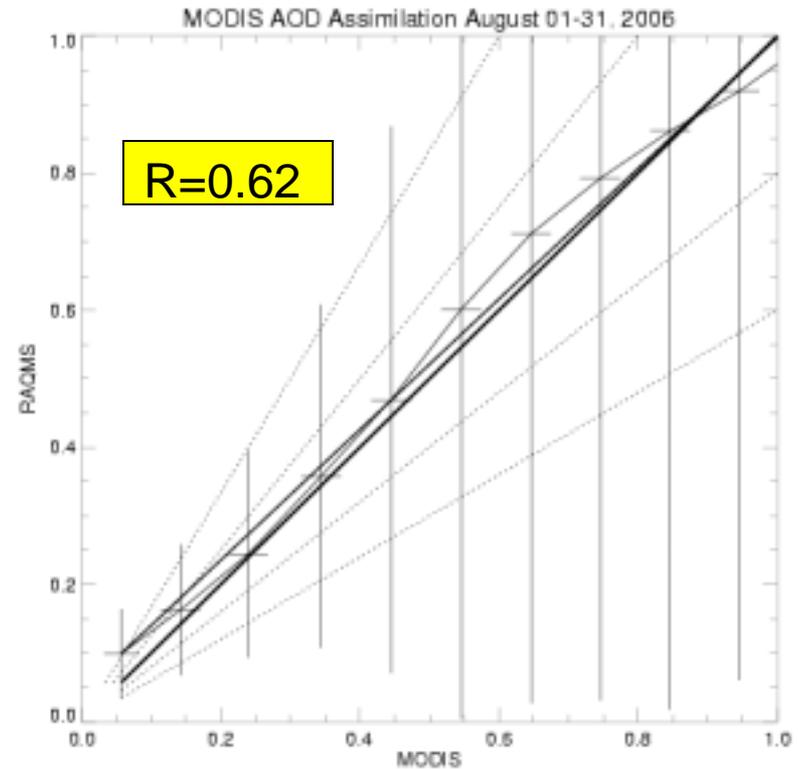
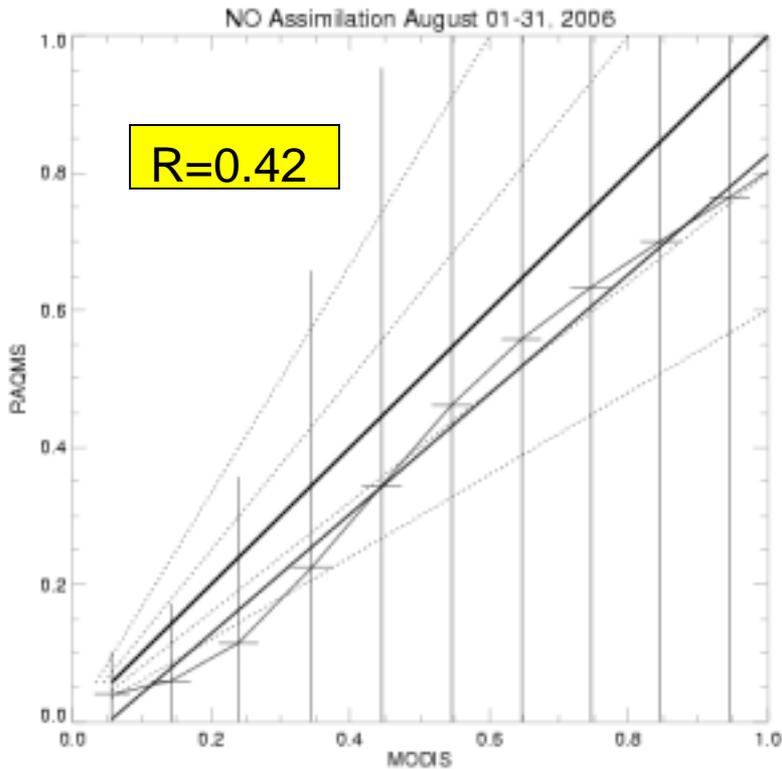
RAQMS AOD Variance (TES/MLS/MODIS Assim)
August 01-31, 2006



MODIS AOD Variance August 01-31, 2006



RAQMS (6hr FX) vs MODIS August 2006 10km AOD Statistics



Assimilation of 1x1 degree MODIS AOD improves correlation with raw (10km) MODIS observations and removes ~ 20% low bias

Summary:

- Assimilation of Satellite ozone retrievals results in agreement with IONS ozonesonde to within +/- 20%
 1. Assimilation of OMI cloud cleared O3 column introduces lower stratospheric high biases
 2. Assimilation of TES O3 profiles introduces lower tropospheric high biases
 3. Assimilation of MLS O3 retrievals reduces stratospheric low bias but introduces tropospheric high bias and overestimates tropospheric variance
 4. Assimilation of OSIRIS O3 retrievals has small impact on stratospheric low biases but reduces tropospheric low bias and improves variance relative to IONS
- Preliminary MODIS AOD assimilation studies show significant improvement in global aerosol analyses

Conclusions:

- Bias corrections are necessary for satellite O3 to have a positive impact on tropospheric ozone.
- Assimilation of OSIRIS Limb scattering and TES IR retrievals builds capabilities for assimilation of OMPS and CrIS measurements on NPP and NPOESS
- Assimilation of MODIS AOD retrievals builds capabilities for assimilation of VIIRS measurements on NPP and NPOESS